Bridging the gap: user centred design and support methods for decision support systems in crop production

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Bridging the Gap:
User Centred Design and Support Methods for Decision Support Systems in Crop Production

By

Caroline Parker

A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of PhD of
Loughborough University

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ABSTRACT

This thesis suggests that there is a problem with technology transfer in crop production. The nature of the problem and the mechanisms available to the agricultural research sector for solving it are examined. As a consequence it is argued that Decision Support Systems (DSS) technology is an extremely useful mechanism for encapsulating and delivering scientific knowledge to the industry. The thesis then poses the question of why this technology is not currently being taken up by farmers and farm consultants, hypothesising that the current lack of user involvement in design is a major contributing factor. The hypothesis is supported by a survey of DSS development and use in agriculture and it is concluded that a user-centred design (UCD) approach is important to the successful adoption of these systems by the industry.

The thesis then asks what methods the agricultural DSS developers should employ to ensure a user-centred design approach. It is suggested that it is not sufficient merely to point DSS producers in the direction of user-centred design but to furnish them with adequate methods and tools to achieve this goal, bearing in mind their specific requirements and limitations and the nature of the decision support task. A review of currently available methods reveals that none of the standard methods meets this requirement and that a new approach is therefore needed. An approach supported by work from management science is introduced. This approach identifies the user’s questions to the system as a means of defining its function and features. Its use in the context of workshops is developed into a user-centred design method to meet all of the requirements for the designer stakeholders. The question approach is also used as the basis of a method for identifying DSS interface requirements and collating design solutions. Both methods are presented as mechanisms for improving the acceptance of DSS in the sector. The document concludes by discussing the contribution made by the thesis to its originating disciplines and looks forward to the future of DSS technology in crop production.

KEYWORDS: Crop-production, Agriculture, Technology Transfer, Decision Support Systems, User-Centred Design, Methodology, Question Approach
For Andy (1964-1992)
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(Appendices are contained within a separate document)
1.0 INTRODUCTION

This thesis is concerned with the application of human factors methods to the development of decision support systems (DSS) for crop production. As such it brings together three fairly distinct areas of knowledge; knowledge about the crop production industry; about decision support systems; and about human factors. The aim of the introduction is to introduce and inter-relate these topic areas and to lay the groundwork for rest of the document.

In Section 1.1 the historical context in which the development of agricultural DSS exists is discussed. Section 1.2 focuses on the present day and the communication problems facing agricultural research institutes for which Decision Support Systems (DSS) may be a partial solution. The nature of DSS is described in some detail in Section 1.3 in an attempt to provide a working definition and to disentangle them from their Management Information System (MIS) and Expert System (ES) relations. Evidence for the general utility of these systems and for their applicability to the crop production domain is also provides in this section, a thread which is continued in Section 1.4. Finally the arguments for the use of DSS as a technology transfer mechanism within crop production are summarised and the research questions to be addressed within this thesis are defined.

1.1 HISTORY OF TECHNOLOGY TRANSFER WITHIN CROP PRODUCTION

1.1.1 Research and information dissemination prior to 1980

Crop production is an important industry in the UK today. Horticulture¹ and Agriculture², taken together, form the second largest primary industry after North Sea oil, use around three quarters of this country's land area, and employ over half a million people (Day, 1990). In 1997 the agricultural contribution to gross domestic product (GDP) was £7,600

¹Production of fruit and vegetables

²Production of 'combinable' crops (e.g. cereals, potatoes, sugar beet) and animal products.
million, about 1.3% of the total (MAFF, 1998). Its importance is reflected in the fact that it has its own ministry, MAFF (Ministry of Agriculture, Fisheries and Food), and has been the target of substantial financial support from successive UK administrations over the course of the last century. Funding of basic research on food production has been one of the main benefactors of this support, an investment which has resulted in an amazing doubling of yields from most crops in 50 years.

The state has not always been responsible for supporting research in this way. At the turn of the century Britain imported 79% of its grain, 40% of its meat, 72% of its dairy produce, 7% of its fruit and 62% of its agricultural feed (HMSO, 1993). This reliance on external supply led to the widespread view that agriculture and horticulture were inessential industries. Those interested in conducting research into food production or any branch of agricultural science at the time did so using private funds. This situation changed dramatically as a result of the threat to vital supply routes during World War I: the realisation that the country was dependent on highly vulnerable links suddenly made self sufficiency in food supply an urgent priority. Almost overnight the position of agriculture changed from 'a pleasant occupation of little consequence' to 'an industry of vital importance to the nation' (Russell, 1966). A direct consequence of this was the promotion, in 1921, of the small and obscure Board of Agriculture to a fully funded Ministry responsible for funding basic agricultural research.

Between 1921 and the early 1980's the Ministry of Agriculture and its successor, the Ministry of Agriculture, Fisheries and Food (MAFF), targeted sector funding at two types of institution, research stations and extension services3 (Ministry of Agriculture, 1989). Each was maintained as a civil service organisation with its activities supported by public funds.

The provision of state aid to support research and extension had in fact begun as early as 1910. Lloyd George, in response to depopulation and the running down of rural

---

3Extension services is the term generally used for centrally funded bodies which disseminate scientific information to farmers and growers.
Introduction

communities set up a grant to expand the resources of the countryside and the coastal regions by 'proper scientific development of afforestation, agriculture and fisheries...with guidance from properly equipped experimental forests and experimental farms, and the setting up of agencies for disseminating agricultural instruction.' (op. cit. p268).

Table 1.1: Pre-1980’s re-organisation list of research institutes and their specialisms

<table>
<thead>
<tr>
<th>Research Institute</th>
<th>Specialism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberdeen</td>
<td>Animal nutrition</td>
</tr>
<tr>
<td>Aberystwyth</td>
<td>Plant Breeding Institute</td>
</tr>
<tr>
<td>Ayrshire</td>
<td>Dairy</td>
</tr>
<tr>
<td>Cambridge</td>
<td>Agricultural Botany</td>
</tr>
<tr>
<td>Cambridge</td>
<td>Animal nutrition</td>
</tr>
<tr>
<td>Cambridge PBI</td>
<td>Plant breeding</td>
</tr>
<tr>
<td>East Malling</td>
<td>Fruit</td>
</tr>
<tr>
<td>Hurley</td>
<td>Grassland</td>
</tr>
<tr>
<td>Littlehampton</td>
<td>Mushrooms, glasshouse, entomology</td>
</tr>
<tr>
<td>Long Ashton</td>
<td>Cider and fruits</td>
</tr>
<tr>
<td>Morley</td>
<td>Arable</td>
</tr>
<tr>
<td>Reading</td>
<td>Dairying</td>
</tr>
<tr>
<td>Rothamstead</td>
<td>Glasshouse crops, soil and plant nutrition</td>
</tr>
<tr>
<td>Silsoe</td>
<td>Agricultural engineering</td>
</tr>
<tr>
<td>Wellesbourne</td>
<td>Vegetables</td>
</tr>
</tbody>
</table>

Research Institutes

The research stations (or centres or institutes as they have variously been named) were established over a number of years. Some like Rothamstead, in Kent, started as privately funded organisations and were brought into the public sector; others, like Wellesbourne, were purpose-built to house a specific group of projects. As the number of research groups increased, a controlling body, the Agricultural Research Council (later the
Agricultural and Food Research Council), was established, initially to fill gaps in provision and later to administer grants and to provide advice to government (Donaldson et al, 1969). While a certain amount of overlap existed between the research areas of the research institutes, each centre had its own specialism, as illustrated in the list in Table 1.1.

**Extension services**

The key mechanism for technology transfer for most of this century has been the 'Extension' or 'Advisory Services'. These bodies provided the mechanism for disseminating the results of research to farmers and growers in a readily usable form. Their importance is indicated by Donaldson who states that 'while the subsidies are the life blood of agriculture and the research services the brain, the Advisory Service acts between the research workers and the farmers as the nerves from the brain to the executive limbs' (op. cit. p179). The worlds of the research scientists and of those at the production end of the industry have traditionally been so far apart that it has been essential for an extension service to exist and to act as a bridge between them.

In the early part of the 20th century this mechanism was provided by 'County Advisers' employed by County Education Departments. These people were expected 'to be fully acquainted with the best existing farm practice, with possible improvements indicated by current research [and] familiar with leading local farmers who might be willing to try out new ideas.' (Russell, 1966. p270). In response to a second wave of pressure on food sources during the second world war the service was expanded, renamed the National Agricultural Advisory Service (NAAS), and made the responsibility of MAFF. Then in 1971 the NAAS was combined with several other services and divisions and renamed yet again, this time becoming the Agricultural Development and Advisory Service or ADAS as it is known today (Wormell, 1978).

The prime function of ADAS and its predecessor NAAS was to keep farmers and growers up to date with best practice in crop or livestock production. Most regions employed some specialists but advisers would be generally qualified to give advice on the whole range of farm issues, from marketing to pest control, soil nutrition to waste...
management. Advisers were expected to keep in touch with the research institutes and current scientific literature and to disseminate new research findings. As they were in daily contact with farms they were also in an ideal position to relay the results (positive and negative) of the practical application of techniques back to scientific staff.

In many cases, the extension services would wait until they had evaluated the practical value of scientific research before disseminating it, collating and translating it into a form which could be more easily understood and used. A good example of this is provided by the series of leaflets published by ADAS on all aspects of farm practice. These documents, small enough to be read easily and pinned on an office wall or kept in a drawer, contained the digested and evaluated results of many years research. Their value is demonstrated by the number of yellowed and usually dog-eared copies still found in use in farm offices around the country.

To summarise, the flow of information in the crop production sector prior to the mid 1980's can be represented as follows:

![Flow of Information](image)

**Figure 1.1: Flow of information in agricultural sector prior to the mid 1980's**

MAFF funded research institutes to carry out basic research into plant processes, the results of which were published in scientific journals and fed directly and indirectly to ADAS. ADAS were funded to collate and refine the research into practical guidelines
for use by the farmer or grower. Feedback on the utility of the advice and on particular areas of interest was obtained by ADAS officers as they toured the farms in their area. In turn ADAS was able to provide feedback to the research establishments i.e. on the direction that basic research should be going.

The picture was obviously not as simple or as rosy as the one painted by Figure 1.1, as Mitchell points out:

'at times the relationship between these two organisations (ADAS & a Research Institute) was so suffused by jealousy and competition for central government funding that not only was co-operation virtually non-existent but at times competition was downright destructive.' (Mitchell, 1996. p15)

However much of the antagonism Mitchell describes appeared just prior to privatisation and was a result of increasing pressure on funding, as supported by an editorial in the Grower in 1992:

'having been told by Government they must market their success or go under.. what choice do R&D institutes have but to scramble for every last commission?' (Editorial, 1992. p1)

Before the changes in funding, which turned co-operation into competition, the mechanism described in Figure 1.1 does seem to have provided fairly clear channels for the dissemination of information up and down the chain, from pure research via extension to the practical realities of day to day farming.

---

4The terms farmer and grower are sometimes used interchangeably, in general however they are distinct, the term farmer being used to denote someone who is involved in arable or livestock production and the term grower to denote someone whose main commercial interest is in fruit or vegetables. As this thesis is concerned with crop production which covers both growers and farmers, the term crop producer will often be used instead.
1.1.2 Research funding from 1980 onwards

The changes that prompted the current research began in the mid 1970's and have continued up to the present day. The increasing costs of supporting a large research and extension service led to a change in philosophy of agricultural funding i.e. that agricultural research should be supported by the nation for the greater public good. Huge increases in yields over a number of years, the diminishment of the fear of a threat to trade routes, and a general shift from public to private ownership of many utilities were some of the factors leading to the change. The Thatcher administration in particular was ideologically wedded to the belief that support for research, which directly benefited an industry, should be funded by that industry. There appeared to be two key practical reasons for this move: a) the removal of a considerable part of the burden of maintaining a large research base in the public sector, and b) the hope that the industry (if forced to pay directly for research) would ensure that it was accurately targeted and carried out more cost effectively. Thus, government could cut costs and move some of the burden of modernising a set of traditional and entrenched civil service institutions to the private sector.

As a direct consequence of these shifts in ideology, radical changes occurred. ADAS introduced charges for some services in 1972, farmers became 'clients', and by 1990 all services were charged. The number of advisers and research departments within ADAS were drastically scaled down during the 70's and 80's, several large scale 're-structuring' programmes took place (many advisers taking their redundancy payments and setting up independently) and by 1995 the service was formally privatised (Grower, 1994).

In the research institutes similar re-organisation took place. Where two groups appeared to be carrying out similar research they were amalgamated (or one was closed down), and research groups were reduced in size. Many of the former research institutes related to horticulture for example, have been amalgamated and re-housed at Wellesbourne under the new name of Horticultural Research International. Funding for 'near-market' research was also drastically cut. Although MAFF continued to offer grants for pure research these were opened to competitive tender and research organisations were expected to
compete for funds against each other; ADAS, the universities, and commercial companies.

Figure 1.2: Cartoon from Grower at the time of the ADAS privatisation (Gus, 1994). Reprinted with permission

To manage and administer funds for near-market research MAFF established new funding bodies, e.g. the HDC or Horticultural Development Council, the Apple and Pear Research Council, the Potato Marketing Board, the Sugar Beet Research, Education and Marketing Committee and the Home Grown Cereals Authority or HGCA. The remit of these groups was (and is) to collect and administer money from their particular sector of the industry; and to use it to fund projects considered to be of benefit to their members. For example the HDC levies each grower with a turnover of above £25,000 a sum of 0.5% of their gross income. These funds are used to support research which is considered to be of direct benefit to the industry. The council itself is composed of growers elected from the different sectors within the horticultural industry e.g. bedding plants, root crops and brassicas.

1.2 THE NEED FOR ANOTHER TECHNOLOGY TRANSFER MECHANISM

1.2.1 Current situation for research funding and dissemination

In summary, in the mid 1980's a massive change occurred in the way in which pure and near market research for crop production was funded and the main source of
disseminating that research, ADAS, was privatised. The flow of information was transformed from the model described by Figure 1.1 to the one described by Figure 1.3.

Figure 1.3: A representation of the flow of research information in the agricultural industry after the changes of the 1980's.

The situation as it stands today is a little more complex than Figure 1.3 suggests. The levy bodies (HDC, HGCA, APRC) do fund most of the near market research but they also fund some of the pure research that wouldn't otherwise be supported by MAFF or BBSRC (off-label trials work for example). Conversely MAFF provides support for some near market research (e.g. the DESSAC project (see Section 3.4) and other technology transfer systems). Research is also funded within private organisations for their own use and for re-sale to the industry. Many product trials are carried out by the ARC (Arable Research Council), an essentially private and independent organisation. Some of the previously public research institutes have become private (e.g. Morley) and others are acting in the expectation that they too will have to stand alone in the not too distant future. Table 1.2 provides an outline of the current players in public and private funding and research in this sector.
Table 1.2: Public and private funders and research bodies in the sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Funders</th>
<th>Research bodies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>MAFF BBSRC</td>
<td>HRI</td>
</tr>
<tr>
<td></td>
<td>HGCA APRC</td>
<td>IACR Rothamstead</td>
</tr>
<tr>
<td></td>
<td>HDC</td>
<td>Silsoe RC</td>
</tr>
<tr>
<td>Private</td>
<td>Distributors</td>
<td>ADAS</td>
</tr>
<tr>
<td></td>
<td>Grower organisations</td>
<td>ARC</td>
</tr>
<tr>
<td></td>
<td>Consultant organisations</td>
<td>Morley RC</td>
</tr>
<tr>
<td></td>
<td>Farmer organisations</td>
<td>Companies themselves</td>
</tr>
<tr>
<td></td>
<td>Seed companies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plant breeders</td>
<td></td>
</tr>
</tbody>
</table>

In the 'free market' research economy of the 1990's public and private research institutes bid for funds from either sector and many research projects combine public and private funds and public and private collaborators; a trend encouraged by funding schemes such as LINK.

The effects of the changes in funding behaviour have had a strong impact on the industry, i.e.:

- Funding for research has become scarce
- Many people now depend directly on the sale of information/expertise for their livelihoods
- Information has become a valuable marketable commodity rather than a freely shared resource

As a consequence the doors of communication previously wide open between institutes, and between the institutes and advisers, are now restricted by contract. Information once freely available has become 'Commercial in Confidence' and all groups, researchers, advisers and growers, are constrained by the financial implications of asking for, or providing, knowledge.
Many senior scientists, by virtue of the changes described in the previous paragraphs, have been diverted from the pure pursuit of knowledge and required to bid for funds. This is a situation directly contrary to the original ethos of agricultural research where, in Sir John Russell's words, there was

'never any pressure on the research workers to find applications of their results to farm practice...they were left to get on with their work in peace." (Russell, 1966, p271).

Unlike their predecessors, senior scientists have to enter the marketplace and bid for 'applied research' funding and any other sources of money they can find. They are on the constant look out for financing, not only to continue working on the topics of particular interest to them, but more fundamentally to keep their research teams together and themselves in employment.

Receiving funds directly from the industry requires research institutes to deliver their findings in a more accessible way. Farmers and growers are not interested in scientific paper style delivery, they need something they can immediately pick up and use. Continued success in bidding for this type of funding therefore requires a new approach. Research Institutes find themselves not only having to carry out the research but also to perform tasks previously carried out by the extension services i.e. verifying and packaging their findings for practical use.

On the advisory side, while some large groups such as ADAS and chemical distributors have their own research teams and can therefore continue to pass information freely among themselves, other advisers have had to spend much more of their time scouring journals and papers to keep up to date with scientific thinking. This is becoming a problem for specialists in many domains trying to keep their knowledge fresh. The growth of the Internet has led to an explosion of information sources of varying quality and there are so many people engaged in the act of scientific discovery that the actual knowledge base for any subject increases hugely each year. The pressure on scientists to publish more frequently has led to a large increase in the ratio of paper to useful knowledge. The art of wading through a mountain of information and locating pearls of wisdom is something which is becoming a marketable skill.
To reiterate the changes in the 1980's mean that the:

- research institutes need a means of generating new income from their knowledge,
- research institutes need a means of communicating directly with the industry, and
- advisers need a faster means of collating and accumulating scientific knowledge.

It would seem therefore that new methods of packaging and distributing scientific knowledge are required.

Immediately after the changes of the 1980's it became apparent that the new structure was causing a problem for technology transfer. MAFF and the BBSRC (Biotechnology and Biological Sciences Research Council) soon began calling for research and applied projects to address the issue and are still putting funds into this area. Although MAFF has generally moved away from funding near-market research, projects which promise to deliver scientific information to the farmer in a digestible form are sometimes supported, for example HORIS (HRI, 1997), a horticultural information system produced by HRI, Morley Research Centre and the HUSAT Research Institute.

To date the research institutes have concentrated their efforts to use new methods on three types of system: decision support, information systems and forecasting services. The next section examines the role of these communication tools in the new environment.

1.2.2 Communication methods

The earlier form of technology transfer, i.e. via the extension services, was carried out within an environment where agronomic information could be freely exchanged. Scientists spoke freely to one another (generally speaking) and to extension workers; information was passed verbally, by report, by lecture etc. It was often possible for an individual grower to contact a biologist directly or to send a specimen of an unknown problem to the relevant research station. An early form of decision support system was designed specifically to deal with the problem of identifying the correct department to which to send samples first! (Parker & Scaife, 1989). (The quantity of small plastic and paper bags containing anything from insects to whole cabbages was sufficient in the late
In the 1990's there is still a considerable amount of face-to-face communication, but it tends to be between consultants and their clients and between scientists or consultants in the same organisations. Inter-organisational communication is more restricted. If it happens it is normally because of pre-existing contacts between individuals or for the specific purposes of a given project.

Figure 1.4 provides a general picture of the forms of communication between the key parties in the technology transfer process in the 1990's. Consultants and the mass media have been forced since the 1980's to rely more on sifting through published work, or to attend conferences and open days, to keep up with scientific developments. However their methods of disseminating this information to their clients has changed little until very recently with use of the fax machine and the growth of email and the world wide web. The mass media have also taken to the Internet and another category of information provider, the closed-group net provider has emerged. Industry interest in web-based services (e.g. Farming On-line, HGCA pages) has been slow but does appear to be gradually gaining ground, if the large numbers at a recent NIAB (National Institute of Agricultural Botany) Internet day (26th February 1998) can be taken as a measure.

Of all groups it is the research institutes which have had the greatest pressure on them to develop new methods. They have responded in a number of ways to exploit their main asset i.e. the vast amount of knowledge they have stored in libraries, filing cabinets and in scientists' heads. These approaches can be categorised as: publications, field walks, meetings and software. It is the latter category, software, which has excited the most
interest, attracted the most funds and generated the greatest level of disappointment and frustration over the last decade.

One reason for the interest is that it is a new technology and therefore exciting in itself. It offers levy bodies the potential for encapsulating scientific expertise and knowledge and making it available to their clients on demand and at low cost. Software gives scientists a chance to produce a 'product' which will ensure their position in the new marketplace. It also presents both parties with an opportunity to give their sponsors something more solid and tangible in return for their investment than the more ephemeral rewards of specialist meetings or field walks (and more interesting than paper-based documents). The frustration and disappointment from software has been due the failure of most of the early systems to engage or keep the interest of growers, farmers or advisers.

The software developed by research institutes has exploited two distinct types of information, a) encyclopaedic and b) model-based, and these are marketed in a number of different ways. Encyclopaedic information is the type of information normally contained in text books, reference manuals, picture libraries, etc. and which can be extracted from experts in particular domains in the form of guidelines or tips for action. Exploitation of encyclopaedic information is a recent development. Examples of encyclopaedic information systems are MORISTM, an arable system from the Morley Research Centre, and its horticultural counterpart HORISTM, marketed by Hortitech Ltd (the commercial wing of Horticultural Research International).

Models

Model-based information is derived from a mathematical expression of the perceived relationships between biological entities. Modelling is a technique which has grown in popularity as methods and computer power have developed to make the process easier. Many models in development today simply could not have been attempted with earlier levels of computing technology. Most of the models in existence are simulation models i.e. time-based, although other forms exist. Their primary purpose is to express an understanding of biological relationships in a form that can be tested against reality and
thereby increase knowledge of those relationships. A secondary but equally important function is their subsequent use, providing they turn out to be a reasonable approximation of nature, as a forecasting aid and as a means of 'what if'ing.

Models can be used as technology transfer mechanisms and sources of income in two ways: as a bureau service, and incorporated into a decision support system, as a software product. An example of their use as a bureau service is provided by forecasting models at HRI (Phelps et al., 1993). These models describe the relationship between the development of two types of common pest (the cabbage aphid and cabbage root fly) to temperature over time. The insects develop at a rate which is very temperature dependent and the growth of a population and the percentage of its members in a given stage of development can be calculated fairly well. Using traps to monitor actual numbers of pests in a given area and given past and predicted weather patterns it is possible to generate forecasts of the threat to crops for individual farmers and growers. This type of service has been very popular with the horticultural industry and a large number of growers subscribe to it.

This type of model could equally well be incorporated into a piece of software for the crop producer or adviser to use by themselves i.e. as a decision support system. Having ownership of the model in this form enables the user to manipulate inputs and to carry out particular 'what if' analyses in addition to securing access to the forecasting provided by the model.

A simple example of a model being used in this way is 'Spacing' (Benjamin et al., 1995), a system commissioned by the HDC. The 'Spacing' program helps growers to decide how far apart to plant carrot seeds in order to produce the largest number of a given diameter (the diameter of a carrot determining its suitability for certain types of market). At the heart of the program is an equation which describes the distribution of carrot sizes based on the values of parameters such as distance between rows, the viability of the seed and the length of time the crop will remain in the ground. As Figure 1.5 illustrates the user interface to the program allows the grower to vary the values of the parameters, e.g.
reduce the distance between rows and observe the effect on the predicted size distribution and suggested seed rate.

A model used as the basis of a bureau service needs few changes from its developmental form to make it usable. The person operating the system is generally the person who developed the model in the first place, and if not, then at least another trained biologist. The operator takes in data provided by the crop producer about current pest/disease conditions, adds in past and predicted weather data, runs the model and sends a forecast back to the crop producer. A model used as the basis for a DSS however is a completely different problem. This type of system will be used directly by crop producers or by their advisers. They will need to input the data directly, understand what the model is doing and interpret the results. The interface to this type of model has therefore to be designed in a completely different way. An additional layer of effort which causes problems for research institutes. Before entering a discussion about current difficulties in developing and selling this type of system however, it will be useful to look more closely at what actually constitutes a DSS.
1.3 DECISION SUPPORT SYSTEMS

1.3.1 What is a decision support system?

The definition of what constitutes a decision support system is not consistent among those who write about them, which is slightly unusual for a technology which has been around for nearly 30 years. The following are examples of the definitions that have been applied:

"interactive computer-based systems, which help decision-makers utilise data and models to solve unstructured problems". (Sprague & Watson, 1986. p8)

"a decision support system is a computer application designed to help people make decisions." (Alter, 1981)

"A DSS is an interactive data processing and display system which is used to assist in a concurrent decision-making process, and which conforms to the following characteristics:
- is sufficiently user-friendly to be used directly by the decision-maker
- displays its information in a format and terminology which are familiar to the users.
- is selective in its provision of information and avoids overloading its users." (Freyenfield, 1984)

"Decision support systems allow co-operation between user and system to improve the quality of decision-making. In DSS a machine's number crunching and memory capability is coupled with human common sense, subjective judgement, and sensitivity to context." (Gammack, 1992)

"a system which, through some combination of expert knowledge, simulation models and databases, can provide support to a decision-maker by providing recommendations on certain management options and/or allow exploration of the consequences of making different decisions." (Keen & Scott Morton, 1978. p 157)

"a system that can be extended, capable of dealing with ad hoc data analysis and decision modelling, where the time horizon is future, usage is irregular and at unplanned intervals." (Moor & Chang., 1983)

"Computer-based systems able to support and enhance managerial decision-making" (Angehnr & Jelassi, 1994)

"a computer-based system that aids the process of decision-making." (Finlay, 1994)

While they all seem to agree on the fact that a DSS is designed to add something to the decision-making process, they disagree on the type of support they provide (i.e. do they...
aim simply to support or to improve the decision process) and the type of problems to which they can be applied (structured/unstructured).

**Background to DSS research**

One of the reasons behind this lack of agreement among DSS researchers is the fact that there is no specific theoretical base underlying this domain. The scientific disciplines which have, and do, contribute to the design and implementation of DSS are many and varied and as Sprague points out,

"people from different backgrounds and contexts view a DSS quite differently. A manager and a computer scientist seldom see things in the same way" (Sprague, 1980. p8).

Angehrn & Jelassi (1994) suggests that the main influences come from Ergonomics, Psychology, Organisational science, AI, and Cognitive science, as shown in Figure 1.6:

![Figure 1.6: Influences on DSS (from Angehrn. p.268.)](image)

An alternative view is proposed by Finlay (1994) who illustrates the influences on DSS (and on the emerging study of Group DSS) from basic subjects like Psychology and Mathematics, through the core DSS topics such as the human-computer interface and logic models.
Angehnm's diagram (Figure 1.6) suggests that all the disciplines contribute equally to DSS, but it is commonly acknowledged (Eom & Lee, 1990) that Management Science/Operations Research (MS/OR) and Management Information Systems (MIS) have had the largest impact on their evolution. The majority of DSS were, and are still today, either computer implementations of MS/OR (Management Science/Operations Research) models and techniques (e.g. optimisation algorithms) or extensions of database systems, traditional MIS or expert systems. Angehnm suggests that this influence can be explained by the academic background of DSS researchers who are mostly from MS/OR or MIS backgrounds.

While it can be seen that are many influences on the development of DSS as distinct entities it is generally agreed that the concept had its beginnings in the work of Gorry and Scott Morton (1971) and that the term was coined by Keen (Keen & Scott Morton, 1978). The history behind the concept of decision support systems began with computerised book-keeping systems. EDP (Electronic Data Processing) automated many previously manual book-keeping functions and at first were seen to be extremely useful. Expectations always rise above the ability of technology to fulfil them however, and soon

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Figure 1.7: Contributions to Decision Support Systems Development (after Finlay, 1994 p 35)
managers were demanding more advanced analysis of the ever-increasing quantities of data computers were generating for their use. A new generation of systems were created, called Management Information Systems or MIS. The purpose of these systems was to sift through data and apply standard algorithms to produce summary data i.e. condensed information in a form that the manager could be expected to use as the basis of his/her decision-making. It was at the point that these systems were also found to be wanting that the term DSS began to be used.

The distinction between MIS and DSS

In their classic textbook 'Decision Support Systems: An Organisational Perspective', Keen and Scott Morton first put the case for DSS as distinct entities. They argue that DSS are distinct on the basis of their differing impact on and payoff to the organisation and their specific relevance to managers. It was probably at this point that the arguments about structure and support, as evidenced in the earlier definitions, were first introduced. MIS, the authors suggest, are mostly:

- used in structured tasks where standard operating procedures, decision rules, and information flows can be reliably pre-defined
- useful for improving efficiency by reducing costs, turnaround time, etc. and for replacing clerical personnel.
- used as indirect supports for the managerial decision-making process i.e. by providing reports and improving access to data.

DSS on the other hand:

- are of most use for ill-structured problems where manager's judgement is essential even though there is sufficient structure for computer and analytic aids to be of use
- have their main benefit in extending the manager's decision-making capabilities by directly supporting the decision process without interfering with the manager's own decision-making style.
Structure

Of the two dimensions, structure and support, structure has been the main focus of discussion for many researchers looking for a way to distinguish between MIS and DSS. Keen and Scott-Morton describe three levels of structure in a task or decision: structured, semi-structured and unstructured. They define these levels as:

Structured: those which don't involve a manager, they can be automated or carried out by untrained personnel e.g. inventory re-ordering, credit scoring, airline reservations

Semi-structured: where some computer support for managerial judgement is required because of the size of the problem or its computational complexity.

Unstructured: tasks/decisions not capable of being automated.

Keen and Scott-Morton looked for examples of task which could be rated on one of these levels of structure within the classic divisions of operational, tactical and strategic decision-making, Table 1.3 displays the results.

They concluded that a DSS could be used to support all levels of managerial decision-making from operational to strategic, provided that the tasks or decisions were semi-structured in nature.

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5Three levels of managerial activity were described by Anthony in 1965: strategic planning, tactical planning and control and operational planning and control. Strategic planning deals with the broad issues concerning the organisation's development over the long term. Tactical planning and control deals with the monitoring of actual production and expenditure against budgets and is medium term between now and next year. Operational planning and control refers to the day to day decisions to stay within targets, meet objectives etc.
Curtis (Curtis, 1989) takes a slightly different view, and proposes a much wider use for decision support systems crossing the border between structured and unstructured. He suggests (as illustrated by Figure 1.8) that DSS can be of use in dealing with structured strategic, unstructured operational and all types of tactical decision-making.

Unstructured strategic decisions are simply too vague and woolly to be supported by DSS and structured operational decisions require no managerial input and can be completely automated.

The Curtis model suggests that the uncertainty introduced into the task by looking ahead in time (strategic planning) creates a need for support in even the most structured task. The example used by Keen and Scott Morton is Plant location, which they suggest can be

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**Table 1.3: A Framework for Information Systems (from Keen & Scott-Morton, p87)**

<table>
<thead>
<tr>
<th>Type of Decision/Task</th>
<th>Operational Control</th>
<th>Management Control</th>
<th>Strategic Planning</th>
<th>Support Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structured</td>
<td>Inventory</td>
<td>Linear programming</td>
<td>Plant location</td>
<td>Clerical, EDP or MS models</td>
</tr>
<tr>
<td></td>
<td>Re-ordering</td>
<td>for manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-structured</td>
<td>Bond trading</td>
<td>Setting market budgets for consumer products</td>
<td>Capital acquisition analysis</td>
<td>DSS</td>
</tr>
<tr>
<td>Unstructured</td>
<td>Selecting a cover for Time magazine</td>
<td>Hiring managers</td>
<td>R&amp;D portfolio development</td>
<td>Human intuition</td>
</tr>
</tbody>
</table>

**Figure 1.8: Potential areas of use for DSS (after Curtis, 1989)**

- A - little support possible
- B - can be aided by DSS
- C - can be automated
Introduction
devolved to an MIS or similar level computer program. Curtis might argue that while the basics of plant location are well understood and can be automated, the uncertainties which occur over time i.e. economic changes, new legislation, etc. require judgement and lend themselves to the use of DSS. The ability to conduct 'what if' analysis, which DSS support, might be critical to framing this particular problem.

Conversely totally unstructured tasks which performed on a daily basis may contain elements which are open to computer-based support. Selecting a cover for Time magazine was classified as an unstructured operational task. While judgements on the aesthetics and topicality of the display may be very difficult to incorporate into a computer program, providing guidance on layout, colour combination etc., and providing tools to enable the user to view possible variations quickly are well within the scope of a DSS.

The value of using structure as an argument at all is disputed by some (Moor & Chang, 1983; Finlay, 1994). Moor and Chang argue that the concept of structure in a task is not meaningful because it depends entirely on the user's perception. Keen and Scott-Morton who started the debate recognised this problem but still argued for the validity of structure as a distinguishing feature. As an example they used the game of noughts and crosses. This game has simple rules which adults know and which generally result in the game ending in a draw, to adults the game is therefore structured. Children however do not know the rules and see the game as unstructured, each move having unknown consequences and with the result in doubt until the end. Real life problems, which we currently perceive to be unstructured, may, they argue, one day turn out to have underlying rules and to be structured after all. In the meantime the absence of total structure in a problem provides a space where DSS can be useful.

Context, or the situation in which the task occurs, may also have profound effects on its structure i.e. there may be situations where structured problems become unstructured. The application of known rules may be completely out of the question or impossible in some circumstances i.e. in emergency or 'fire-fighting' situations. While not dismissing the use of structure as way of distinguishing between systems, Keen and Scott-Morton
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suggested that it was the system builders' tendency to dwell too much on inherent structure which caused many of the usability problems with MIS i.e. 'Managers are often irritated by the tendency of management scientists to focus on the inherent structure of a decision... ignoring the context that makes that irrelevant.'

It is also true that problems are not always structured or unstructured in their entirety but only in terms of particular phases within the problem-solving process. Using Simon's three stage definition of the problem solving process:

- Intelligence - searching the environment for conditions requiring action
- Design - inventing, developing and analysing possible courses of action
- Choice - choosing one from those available (Simon, 1960. p2-3)

Keen and Scott-Morton proposed that a fully structured problem is only one in which all three phases are structured.

Support

The other key difference between DSS and MIS, initially suggested by Keen and Scott-Morton and then taken up by other researchers, is 'support' i.e. the way that the user is supported during the task: DSS, they felt, are intended to:

- assist managers in their decision processes in semi-structured tasks,
- support rather than replace, managerial judgement, and
- improve the effectiveness of decision-making rather than its efficiency.

The emphasis is therefore not on taking jobs away from the manager (or the clerk for that matter) or necessarily on speeding things up (although that may be a side-effect), it is on supporting and improving the decision-making process. MIS on the other hand have been designed largely to improve efficiency and replace human activity with computerised functions.
Introduction

Summary of the MIS/DSS debate

Since the publication of Keen and Scott Morton's book in 1978 the debate on the
distinction between MIS and DSS has evolved and produced a number of 'camps' of
opinion. Some believe that MIS and DSS are the same thing e.g. Naylor (1982) and
Finlay (1994). Finlay for example maintains that the term DSS should be used to
describe any system that provides management information (MIS) or management
intelligence (MINTS), and that all aspects of managerial problem tackling that are helped
by the use of computers should be covered by the term. Others believe that DSS are a
sub-set of MIS (e.g. Hall, 1983), and many more that MIS and DSS are overlapping but
distinct systems (Alter, 1981; Keen & Scott Morton, 1978; Moor & Chang, 1983; Hall,
1983; Sprague, 1980).

The structure of the tasks to which the systems apply (MIS for structured tasks and DSS
for semi-structured tasks) has been the keystone of most of the arguments in this debate,
and all of those who see them as at least partially separate entities identify this as the
main reason. Those who feel that structure is too user-dependent to be a useful concept
(i.e. Finlay, Moore and Chang) make no distinction between the two systems. However
as the examples provided by Keen and Scott Morton illustrate, perception is reality to the
perceiver i.e. if all managers fail to perceive the rules in a task then it is unstructured, and
until some structure is defined little can be provided in terms of support. The more
structure that becomes apparent, the more computerised the task can become. Alter
suggests that the argument about structure is irrelevant as developers of DSS generally

"ignore the rhetoric and build as much structure as they can into their DSS solutions."

This thesis would argue that the distinction between MIS and DSS is largely historic, that
MIS are the forerunners of DSS and are incorporated within them. While structure is a
useful distinction to make between MIS/DSS, the better one is based on the level of
support they provide. The term Management Information System suggests a system
which feeds information to the manager and MIS have traditionally been systems which
use the structure identified in a task to automate a process and provide information to the
manager. They have been the computerised equivalents of clerks who generate reports and leave them on the manager's desk. They do not, as such, support the decision process any further than the provision of information. DSS on the other hand are designed specifically to support the process itself. A DSS provides information but it should also, based on a thorough understanding of the decision process, provide it in such a way that the decision becomes easier and more effective. A DSS is the equivalent of a personal assistant or a governmental private secretary. Like any person in such a position a DSS is also capable of providing information in such a way that some types of decision are more likely to be taken than others. They therefore go far beyond the passive presentation of information, supporting the process and often actively aiming to improve it. The view which this thesis takes of the relationship between DSS and MIS is reflected in an amended version of a diagram from Finlay (1994) as shown in Figure 1.9.

Figure 1.9: The relationship between MIS and DSS (after Finlay, p41)
Unlike the other views expressed by the Venn diagrams, this thesis perceives DSS as an extension of MIS. They are functionally distinct but only in that they take the functionality of MIS and add a further layer which is directly concerned with the support of the decision-making process and as such requires knowledge of the decision-making process within its design (Stabell, 1983).

**Choosing a definition for DSS**

Keen & Scott-Morton described what they perceived to be clear distinctions between DSS and MIS because they felt that the differences between the systems has led to many failures in development. The need to define clearly the characteristics of these systems was driven by the need to redefine the development process and provide a framework for good design. This approach, i.e. defining the scope of the subject in order to provide boundaries to the framework is also adopted by Sprague and Watson in another classic text 'Decision Support Systems: Putting Theory in Practice' (Sprague, 1986). It seems therefore to be a useful format to adopt for a thesis which is also driven by the need to provide additional structure for the design and development of DSS.

In the light of the discussions above a definition will be attempted on the basis that it

"... can be neither right nor wrong; only be more or less useful" (Finlay, 1994. p. 29).

Avoiding the problem of identifying the task types for which such systems may be useful and focusing instead on the nature of the support provided, for the purposes of this thesis and for postulating additions to a DSS development framework, a decision support system will be defined as:

'a computer-based system designed to help its user to make more effective decisions by providing information in a way which actively supports the decision process' 

**1.3.2 What's inside a decision support system?**

The act of defining a DSS has suggested the types of things that such a system should contain but has not as yet explicitly identified them. Traditional DSS are comprised of components which directly address three stages of decision-making, intelligence, design
and choice, defined by Simon (1977). They normally contain a means of supporting the storage, manipulation and access of data; of fitting this data into formal models; and of using the models to make some decisions.

Table 1.4: Components of a DSS

<table>
<thead>
<tr>
<th>Stage</th>
<th>Component</th>
<th>Supports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intelligence</td>
<td>Databases</td>
<td>Storage, manipulation and access of data</td>
</tr>
<tr>
<td></td>
<td>'Encyclopaedic' information sources</td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>Process models</td>
<td>Fitting this data into formal models</td>
</tr>
<tr>
<td></td>
<td>Rule-bases</td>
<td></td>
</tr>
<tr>
<td>Choice</td>
<td>'What if' facilities</td>
<td>Using the models to make some decisions</td>
</tr>
<tr>
<td></td>
<td>Optimising models</td>
<td></td>
</tr>
</tbody>
</table>

The typical components of a modern decision support system shown in Table 1.4, are databases, encyclopaedic information sources, process models, rule bases, 'what if' facilities and optimising models. A DSS may contain simply a database and process model or it may make use of all of these components. A description of each component is given below:

**Databases**

A database is a collection of logically related records or files (O'Brien, 1993). Databases traditionally allow data to be stored, sorted and accessed. A number of different types of database have emerged as a result of distributed processing, end user computing, decision support and executive information systems. Six main varieties can be identified:

*Operational database*: Storing detailed data needed to support the operations of the entire organisation. e.g. customer or personnel databases, inventory database, etc.

*Management database*: Store data extracted from selected operational and external databases. They consist of summarised data and information essential to
management function. Most often used as part of decision support system and executive information systems to support managerial decision-making.

**Information warehouse database:** Stores data from current and previous years that has been extracted from operational and management databases. Central source of information which has been standardised and integrated for use throughout the organisation. A major use is "pattern processing" where key factors and historical trends in business operation are identified.

**Distributed database:** Parts of a network of databases, storing locally relevant information as well as globally required information.

**End user database:** Store information collected by users for their own use.

**External database:** Store information which is maintained and sold for use by private companies.

While it is the management database type is most commonly found in mainstream decision support systems, DSS may make use of other types as well. The DESSAC project (see Section 3.4) can potentially make use of management, end-user, external and operational databases.

**Encyclopaedic information sources**

An encyclopaedic information source is one in which data of a reasonably static nature (e.g. facts, statistics, pictures) are contained. They are essentially electronic books. Examples of such materials are Encarta™, a popular home encyclopaedic resource, and HORIST™ and MORIST™ which are commercially available horticultural and arable information systems. In contrast to their paper-based predecessors these can be updated at less cost and therefore more regularly.

**Models**

Human decision-making is based on models. Humans from an early age create and manipulate mental models of reality as a means of trying out solutions before having to
commit to them (Craik & Lockhart, 1972). We each hold within our heads mental models, built up over time, of people and situations we know. If for example we have to give someone a piece of bad news we might run the scene over and over in our heads trying to find the best way of approaching that particular person. Mental models are employed by everyone at all levels of decision-making, and at any point are representations of our state of knowledge about a given person, system or set of circumstances. Mathematical and simulation models are external versions of their mental counterparts. In one approach to developing a mathematical model of a biological process the biologist starts by sketching out a personal understanding of the relationships between entities (Parker, 1995); this is a direct transfer from an internal model built up as a result of experience. Having externalised the shape of the relationships the 'intuitive' understanding of the mechanisms that shape those relationships can then be introduced. Finally the intuitive understanding is translated into mathematical form using experimental data to define and refine initial assumptions. The model, externalised and made concrete is then open to testing and practical use.

**Rule-bases**

Expert systems are defined as "computer-based information systems that use... knowledge about a specific complex application area to act as an expert consultant to users" (O'Brien, 1993). A rule-base is a set of 'rules' for a problem situation extracted from an expert and is one of the three key components of such a system. The other two components are a data store and an inference engine. The inference engine looks at the current state of the world as contained in the data store and fires any rules which apply to it. A disease identification system might contain a number of diagnostic rules relating to the physical manifestations of the disease. Presented with a set of physical symptoms it would check its rule base for any that apply, eliciting further information from the user as it progresses. e.g. a simple example of the type of dialog is shown in Table 1.5.

Rules are essentially representations of an experts mental model of the problem. One of the methods for eliciting rules is to present the expert with sets of a problem situation and ask him/her to come up with ways in which two of the problems are the same or different
from the third (Card sort or Method of Triads). The expert can only do this by examining the mental model of the problem situation.

Table 1.5: Example of Expert System Dialog

<table>
<thead>
<tr>
<th>Expert system query/display</th>
<th>Data</th>
<th>Possible solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the problem?</td>
<td>Red spots</td>
<td>Measies, Chickenpox, German measles, Meningitis</td>
</tr>
<tr>
<td>Are they large or small</td>
<td>Small</td>
<td>Chickenpox, German measles, Meningitis</td>
</tr>
<tr>
<td>Do they disappear when the skin is pulled?</td>
<td>No</td>
<td>Chickenpox, German measles</td>
</tr>
<tr>
<td>Is there a high temperature?</td>
<td>No</td>
<td>German Measles</td>
</tr>
<tr>
<td>Diagnosis = German Measles</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

People, as a rule do not engage in exhaustive searches when generating “rules of thumb” and while rules can be useful errors do occur. For example, it is known that people are likely to judge events which come readily to mind as more likely to occur than those which take effort to generate (Rasmussen et al, 1987), recent events may therefore be incorrectly rated as more likely than distant ones. Rules, as representations of an internal human process with known flaws, are unlikely to be as useful as a simulation model and are also very hard to test (Berry, 1990). A simulation model on the other hand is a mathematical representation of the knowledge about a situation or system and can be supported and developed by empirical testing. In situations where there is limited data and modelling is therefore not an option, or in situations where the relationship between entities is extremely simple, an expert system approach might be more appropriate.

'What if' facilities

'What if' analysis describes the process of observing the way in which changes to selected variables affect other variables in a mathematical model. A model permits the user to observe the effects of different situations (or scenarios) on the outcome of a decision, or to look at the effects of different solutions to a problem. This is a mechanical form of the process discussed above in relation to mental models, i.e. trying things out in a safe environment before testing them in the real world. Just as the mental 'what if'ing process
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may prevent us from giving someone a heart attack by breaking bad news to them in a clumsy fashion, mechanical 'what if'ing facilities can support the optimisation of business decision processes in a risk free environment. In its simplest form a 'what if' facility presents the user with a list of inputs and outputs to the model, supports alteration of the inputs and observation of the corresponding changes to the output.

Optimisation programs

While a simulation or process model will calculate the outcome of a given set of actions or inputs this may not be enough to support the decision process. In complex situations, where a number of different variables are being manipulated, the decision-maker may want to make use of the processing power of the computer. An optimisation program will generate and/or sort through a large number of potential solutions to find those which most closely match the requirements specified by the decision-maker. For example, given a hundred different crop varieties, an optimisation program might sort them according to characteristics specified by the user leaving them to make the final decision between a much smaller set of top ranked varieties. In DESSAC the optimisation program is used to identify the best spray programs by repeatedly running a process model with different dates, rates and number of applications (Parsons, 1997).

1.3.3 What's the difference between DSS and Expert systems?

The earlier part of this document described the difference between MIS and DSS. DSS have also been confused with Expert Systems. This thesis would argue that the definition chosen for DSS in Section 1.3.1 clearly separates the two types of system.

An expert system is not a decision support system according to the definition stated above because it is not designed to actively support the decision process but instead to supplant it. An expert system by its nature is designed to carry out some of the functions of an expert i.e. to make expertise more widely available to those who need it. Expert systems are designed to be used by people who would normally ask an expert for an opinion or diagnosis, etc.
One example of a successful expert system is the Pinder Yellow Pages expert system (DTI, 1993). This system is designed to format the entries in a yellow pages layout so that the minimum amount of fillers are required. It is completes this task without human interference. This is a task which used to be painstakingly carried out by a large team of human experts. The Pinder system replaces the decision-making expertise of that team.

Another example slightly closer to a decision-making system is the Shapfell Lime Kiln expert system (DTI, 1992). This system monitors the conditions inside the lime kilns and alerts the operator to potential problems. It also suggests solutions. This system may therefore be seen to be supporting a decision process and it is, but not by design. The system was not created with the intention of supporting a decision process, it was created to replace some of the attentional skills of the operator (peoples attention levels vary throughout a shift, especially late at night) and to replace some of the need to seek an over-stretched expert's advice. In the same situation a decision support approach might have used an interface device such as the 'integral display' (Coury & Boulette, 1992) to support the operators own decision-making and reduce the cognitive load. It might suggest solutions to problems but would not be prescriptive. The difference between an expert system and a decision support system is that an expert system does not support the user in making 'more effective decisions by providing information in a way which actively supports the decision process', it simply makes the decisions. This view is supported by Turban & Watkins (1986) who produced a table highlighting the differences between the two systems (see Table 1.6). They suggest that DSS are designed to assist humans and leave the human in charge of the decision-making whereas ES replicate human performance and take the decisions themselves.

The dividing line between DSS and ES is however a little more fuzzy than Table 1.6 suggests; some expert systems have been designed with the express purpose of supporting those who make decisions e.g. MYCIN, one of the earliest medical examples.
<table>
<thead>
<tr>
<th>Heading</th>
<th>DSS</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Assist human</td>
<td>Replicate (mimic) human and replace him/her</td>
</tr>
<tr>
<td>Who makes the decision?</td>
<td>The human</td>
<td>The system</td>
</tr>
<tr>
<td>Major orientation</td>
<td>Decision-making</td>
<td>Transfer of expertise (human-machine-human)</td>
</tr>
<tr>
<td>Query direction</td>
<td>Human queries the machine</td>
<td>Machine queries the user</td>
</tr>
<tr>
<td>Clients</td>
<td>Individual and/or group users</td>
<td>Individual user</td>
</tr>
<tr>
<td>Manipulation</td>
<td>Numerical</td>
<td>Symbolics</td>
</tr>
<tr>
<td>Problem area</td>
<td>Complex, integrated, wide</td>
<td>Narrow domain</td>
</tr>
<tr>
<td>Data-base</td>
<td>Factual knowledge</td>
<td>Procedural and factual knowledge</td>
</tr>
</tbody>
</table>

It can be argued however that the reason that most of the attempts to produce expert systems in this domain have resulted in failure (De Dombal, 1993) is that they are not DSS i.e. they have not actually attempted to understand the decision process. De Dombal, in a review of knowledge-based systems use in medicine from 1995 suggests several reasons for their widespread failure:

- failure to give users what users want
- failure to be integrated into clinical practice

There is no doubt that the systems contain information which could be of value to those they are intended to support but the information is simply not presented in a way which is usable within the decision context, i.e. "clinicians will not use systems (whatever their merits) which do not lend themselves to integration into their clinical practice, simply because they are too busy to do so." (De Dombal, p.219). The same paper suggest that "It may be necessary in the next ten years to expend considerable thought on the way in which information from knowledge-based systems is to be displayed".
Would an Expert System or Knowledge-based System, which was specifically designed to support the decision process, by definition then become a decision support system? This thesis would support such a view. It is the way in which the presentation of information is structured, with the specific aim of supporting decisions that makes a DSS what it is.

It is possible to imagine a continuum in computer-based 'support' systems, from those which are totally passive in the decision-making process to those which are totally prescriptive (see Figure 1.10) On the far left is a system whose purpose is simply to bring together all of the information the user might need to make a decision. At this end of the continuum no effort is made to interpret the data. The user has total control over interpretation and decision-making.

In the centre of the continuum the introduction of data interpretation has removed some of the user's control. Models and/or rule bases manipulate and interpret the data in some way and display the results. The data and the manipulations are arranged so that all the information the user needs is to hand, as previously, but this time some of the labour of interpreting it has been removed. The information, ideally, is arranged to support the user in their specific task context. At this level of support, it is the user who decides what the 'optimum' solution is or if there is a problem, based on the interpreted data they see on the screen. The user is further supported by presentation and dialogue methods sensitive to the user's access and information organisation needs. Some control is removed from the

Figure 1.10: Continuum of support from no interpretation to total interpretation
user in this situation but only in as far as carrying out calculations which the user would find impossible, or at least tedious.

On the far right of the continuum is a system which actually takes the decisions for the user. It may contain a high level rule-based description of an expert approach to the problem. At this end of the continuum the system carries out the analysis on the data as before but also delivers an optimal solution as well. The classic expert system would sit at this end of the continuum, delivering diagnoses and solutions to passive users.

Decision support systems on the other hand are closer to the centre. Having another party make suggestions for action is useful however, and it should not be assumed that decision support systems cannot suggest optimal solutions. Decision support systems can provide this type of information in addition to all the other types of information the user needs to make an independent assessment.

To summarise the difference between a DSS and an ES, it can be argued that the DSS is designed to support the expert decision-maker while the ES supports the non-expert or supplants some routine aspects of expert decision-making. Decision support systems express their understanding of the decision process in the type of support they provide at the user interface. Expert systems are a materialisation of that understanding.

1.3.4 What are DSS useful for and where are they used?

Having defined DSS and extricated them from entanglement with MIS and ES, it would be useful to examine their function in more detail and to look at the situations and sectors in which they have been developed. Keen and Scott Morton suggest that DSS are most likely to be useful in situations where there is:

- Too large an database for a manager to access and make conceptual use of.
- A need for manipulation or computation in the process of arriving at a solution.
- Time pressure on the decision.
• A need for some judgement, either to recognise or decide what constitutes the problem, or to create alternatives/choose a solutions. The judgement may define the nature of the considered variables or the values that are put on them.

The size of the database and the need to perform complex calculations on it under time pressure suggests the role of the computer, and the need to use judgement suggests the role of the human component in the process.

**Business & financial applications of DSS**

DSS were first suggested and designed for upper management in large corporations where this type of situation is common e.g. the FPS system (Olson & Sprague, 1986). This system was first developed to try to solve a problem faced by the Louisiana Bank in Baton Rouge which found itself not making money and with excessive short term borrowing. The bank had history of innovation and decided it needed something to help manage the bank at the highest level, especially in the areas of profit planning and liquidity analysis. The FPS extracts data from primary management information systems and presents summary reports, 12 month forecasts and five year forecasts on a 'constant horizon basis'. It also analyses the historical data and emphasises key/liability management issues. In its first year it was responsible for an increase of 92% in profits. The system was based on an extensive analysis of the existing manual system and is essentially a summary model of the bank’s automated financial control system. It operates in an on-line computer environment which gives managerial access at any time, permits experimental forecasting to test alternative assumptions and strategies, uses its own independent data base, and permits rapid redesign to accommodate changing circumstances.

Other business and financial DSS include systems designed to support investment (e.g. Chou et al., 1997; Lieb and Gillease, 1996; Vranes et al., 1996), loan management (e.g. Ding and Yeo, 1996; Glasen et al., 1994; Plenert, 1996), personnel careers management (e.g. Bellone et al., 1995) and project planning (e.g. Chu et al., 1996).
**Manufacturing applications of DSS**

Although the traditional home of decision support systems has been the business/financial sectors there are an increasing number of examples of DSS in the manufacturing sector.

The MDS/COMPASS system (Hehnen et al., 1986) was created to solve a manufacturing problem in the lumber industry. The problem was concerned with 'Merchandising' i.e. cutting logs into the most profitable pattern of pieces. Making good decisions about where to cut the stem is a sophisticated optimisation problem and this was the initial stimulus for the development of the real time decision and control system (MDS) and COMPASS (a DSS and simulation system). The MDS consists of a data acquisition device which acquires information about the stem's geometry, a processor to compute and optimise decisions and control system interfaces for interacting with the operator and saws. COMPASS is a DSS which helps mill management determine the effects of the decision systems logic and explore alternative merchandising strategies.

More recent examples can be found in the areas of: plant design (e.g. Chau and Bell, 1994) product sourcing (e.g. Chaharbaghi, 1994); supply network design (e.g. Padillo et al., 1995); scheduling and control (e.g. Hu et al., 1995; Schniederjans and Carpenter, 1996); textiles (e.g. Tu and Yeung, 1997), food (e.g. Zwietering et al., 1993) and micro-electronics (e.g. Fargher et al., 1994) as well as in the more traditional heavy industries.

**Medical applications of DSS**

Another domain where data manipulation, time pressure and human judgement are brought together on a regular basis is clinical medicine. As Reisman states

"The gap between existing information and that accessible from memory at the time of the clinical decision-making process is difficult to close" (Reisman, 1996. p179).

The potential for the use of DSS within medicine has been recognised since the mid 50's and there have been many attempts to create systems to support hard pressed clinicians and hospital administrators. It seems that even Chinese medicine has received attention with the development of a DSS for the diagnosis and treatment of chronic hepatitis (Zhao et al., 1994).
An interesting development in this area is the emergence of integrated clinical decision support systems. These systems are intended to support a wide range of health care professionals by using data obtained from previous clinical studies to predict the most probable diagnosis and treatment alternatives for a presenting patient.

The reasons which have been given for the use of DSS in clinical practice have been reviewed by Reisman (1996). These are: making knowledge and expertise of human experts more widely available; supporting the formalisation of medical knowledge; improving the accuracy of clinical diagnosis, improving the reliability of decision-making; improving the efficacy of tests and therapies by balancing funds against benefits; improving the understanding of the structure of medical knowledge and medical decision-making, improving training in diagnostic techniques by simulating situations for medical students; and highlighting gaps in current knowledge (op. cit., p. 180).

Many of the medical systems described in the literature have been developed to support the diagnostic procedure, e.g. INKBLOT (Citro et al., 1997). INKBLOT-1 is designed to support the diagnosis of neurological disorders by combining the behaviour of a human expert with the memory and processing advantages of the computer to generate novel hypotheses. Other examples of recent diagnostic systems, ranging from paediatrics to pathology to psychiatry can be found in Bartels et al., 1995; Dupuits and Hasman, 1995; Hamilton et al., 1996; Leonhardt et al., 1997; Zeilinger et al., 1995; Plant et al., 1994). Other types of system include: those designed to support health authorities and managers (e.g. Mcclean and Millard, 1995; Morgan, 1996); providing guidance on practice and regulations (e.g. Lobach and Hammond, 1997; Pestotnik et al., 1996); patient monitoring (e.g. Bottino et al., 1997; Fitzmaurice et al., 1996; deGraaf et al., 1997); and risk assessment (e.g. Ferns, 1995).

**Waste and water management applications of DSS**

This is another area in which the type of support offered by DSS technology seems to be increasingly important. An example of a water management system is provided by Andreu et al. (1996). This paper describes a generic decision support system (DSS) which is designed to support the planning and operational stages of decision-making.
associated with complex river basins. Computer-assisted design modules are used to represent complex water-resource system to be represented in a graphical form, and users are given access to geographically referenced databases and knowledge bases. The system described within the paper is currently being used by two River Basin Agencies in the management of their water resources. Most of the other water related DSS are also concerned with the effective management of this precious resource either on a national or regional scale (e.g. Ford and Killen, 1995; AlShemmeri et al., 1997; Fredericks et al., 1998) or on a local scale relating to agricultural irrigation particularly in arid countries such as India (e.g. Arumugam and Mohan, 1997; Datta, 1995).

The use of mathematical models to support those involved in waste management is increasing (Barlishen and Baetz, 1995) and a number of model-based and other DSS now exist in this area. Examples include: MacDonald (1996), a 'spatial decision support system' or SDSS for solid waste disposal planning which incorporates factors such as economic costs, legislative requirements, land use, pollution generation, resource usage and equity in the number and demographics of people affected by a plan; Paige et al. (1996) which supports the selection of the means of 'capping' such sites once selected; and Okubo et al. (1994) & Pinter et al. (1995) both of which describe systems which support the treatment of waste water.

**Safety applications of DSS**

DSS technology is being used in a number of domains to support those in charge of managing emergencies, for example in the case of wildland fires (e.g. Guarnieri and Wybo, 1995; Weiss et al., 1993), forest fires (e.g. Wybo et al., 1995), nuclear power station disasters (e.g. Kelly et al., 1996; Winter, 1997), hurricanes (e.g. Tufecki, 1995), and freeway problems (e.g. Zhang and Ritchie, 1994). In all of these cases a lot of information has to be analysed rapidly so that decisions about deployment of safety staff and resources can be handled efficiently.

**Use of DSS in Crop Production**

Crop production combines some of the dynamics of medicine and some of manufacturing engineering. The aim of crop production is, in common with manufacturing, to create
and sell a product. That the product is biological in nature and most of the factory floor is outside does not detract from the fact that many of the processes are very similar. Stock has to be ordered (seed, chemical treatments, etc.), supply has to be balanced against demand, goods have to be packaged, stored and delivered, customers have to be kept happy, and the myriad activities on the 'shop floor' have to be organised in the most effective way.

Similarities to medicine are created by the biological nature of the product. In common with other biological entities, crops are prey to a whole hosts of diseases and disorders. Maintenance of general crop health and the diagnosis and treatment of problems, before they cause a reduction in profitability, are key activities in the crop production year. Those engaged in these activities, like clinicians, must be alert to key symptoms and decide which of many possible treatments will be most effective, often under conditions of extreme time pressure. Mistakes can be costly as single fields, particularly of vegetable crops, may be worth many thousands of pounds. Treatment costs are also high, sometimes as much as several hundred pounds a hectare, where an average farm may be between 50 and 1000 ha in size. Many farms operate on the borderline of profitability and a mistake in treatment can therefore make the difference between profit and loss. Farmers have one of the highest suicide rates in the UK (Mullin, 1996) almost twice that of the general population (McGregor, 1996) and there is no doubt that the pressure of decision-making on this scale contributes to it.

The potential for such systems in this sector is obviously high. In addition to helping the hard-pressed crop-producer avoid financial loss, a more recent interest has been to reduce or to target more effectively the application of chemical products. Recent systems include those for pest and disease management in crops like cereals (e.g. Longstaff and

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6Effectiveness is of course measured in different ways. In medicine, it is not possible to determine the 'cost-effectiveness' of the treatment in an objective way, although no doubt many hospital administrators attempt to do so. In crop production cost effectiveness is a fairly simple calculation of the expected return on the crop with or without treatment. In cases where the damage to the crop is so extensive or the value of the crop so low a decision not to treat may be taken.
Cornish, 1994; Secher et al., 1995); soybeans (e.g. Stone, 1990) and field beans (e.g. Fisher et al., 1997). Weed management (e.g. Odonovan, 1996, Oryokot et al., 1997, Stigliani et al., 1996) is also attracting development effort as are nutrition-based systems particularly those which help to prevent run-off and pollution problems (e.g. Vandendriessche et al., 1996; Young et al., 1995)

Other crop and crop production related DSS mentioned in recent publications include: irrigation support systems which use either sensors e.g. (Thomson, 1996), or models of soil type and soil-water property (e.g. Leenhardt, 1995) to provide an indication of irrigation effectiveness; systems to support effective use of cultivation (e.g. Thangavadivelu and Colvin, 1997; Daniells et al., 1996); systems to manage crop timing and appearance (e.g. Fisher et al., 1997); and management of stored crops (e.g. Wilkin & Mumford, 1994). Finally there are systems which are not single DSS but contain groups of them, each providing support for a different aspect of crop production but sharing the same common database; the DESSAC system outlined in Section 3.4 is one example of this type of system, as is Orchard 2000 (Laurenson, 1994) and the Danish PC-Plant protection system (Pedersen et al., 1997).

1.3.5 How do DSS support the decision-making process?

Actively supporting the decision process requires some knowledge of the way in which humans make decisions. The dominant model of decision-making adopted by DSS researchers is the first three stages of a process proposed by Simon (Simon, 1977) i.e. intelligence, design and choice, described below.

- Intelligence: where the decision-maker searches the environment for problems that need to be resolved. The term intelligence being used in the military sense of collecting information.

- Design: where the decision-maker identifies the range of alternatives available to solve the problem, and their implications.

- Choice: where the decision-maker chooses which of the alternatives is most suitable.
The model is used as a means of explaining the process of decision-making and to derive the characteristics of decision support systems (Angehyn & Jelassi, 1994). Angehn and Jelassi (op cit.) believe the wide adoption of this model, which provided a sound conceptual basis for developing the first generation of DSS, has become a serious obstacle for the evolution of DSS theory and practice. They suggest that adopting different models of decision-making might lead to different DSS designs and go on to discuss potential approaches.

New approaches they suggest might emerge from:

I. the relaxation of the basic assumption that managerial behaviour is mainly guided by deductive logic and full or bounded rationality as suggested by Simon's model.

II. shifting the focus from the choice phase - in which alternatives are evaluated and selected - to other phases of the decision-making process, such as problem structuring/framing, creativity and idea processing, post decision analysis, feedback analysis, etc.

They believe that adopting such a model might result in the re-evaluation of decision-making as a learning process, a possibility also suggested by Keen and Scott-Morton (1978). Such an approach would produce DSS whose main objective was to provide flexible environments through which learning about a decision process can take place. They also feel that much could be gained by focusing not on any specific theory of decision-making but on observing the types of biases which occur in real decision solving situations and using this knowledge to prevent mistakes caused by them.

The idea of focusing on real decision-making rather than on a theory of decision-making is given support in a recent paper by Cannon-Bowers et al. (1996). The authors, although speaking from decision-making research rather than from a decision support research background, make many points which are relevant to the Angehn argument. There is, they suggests, a paradigm shift towards a more naturalistic perspective within the decision sciences,
"classical decision-making research was seen as focusing on sterile, contrived decision-making situations, with results that were of little consequence to real-world decision-makers." (op cit. p, 193)

This dissatisfaction led to a conference in 1989 in Ohio which directly addressed the topic of naturalistic decision-making, and from there to an increasing interest in the subject.

Orasanu and Connolly (1993) suggest that it is not feasible to apply classical decision-making research analyses to many situations in real-life because it fails to account for decision-maker experience, task complexity, and the demands of the naturalistic environment. This new approach, Cannon-Bowers, argues seeks instead to focus on realistic decision environments i.e. on decisions that are 'embedded in larger dynamic tasks, made by knowledgeable and experienced decision-makers'.

Orasanu and Connolly (op cit.) identified eight factors that characterise the boundaries of naturalistic decision-making, many of which agree with the definitions discussed earlier in this thesis (Section 1.3.1) of what constitutes a good problem for a decision support tool. These are:

- ill-structured problems
- uncertain, dynamic environments
- shifting, ill-defined or competing goals
- multiple event-feedback loops
- time constraints
- high stakes
- multiple players
- organisational norms and goals that must be balanced against the decision-makers personal choice

Unlike decision support scientists however, naturalistic decision-making researchers seek 'to describe - not prescribe - decision-making in real environments'. They are not happy
with the idea that there is an ideal way to make decisions and that therefore there are some flaws in the ways that human decision-makers function. This does not sit easily with the idea of DSS. DSS researchers might happily adopt the idea of supporting a more naturalistic approach but will naturally not support the idea that their services are not required. The driving force behind the development of most DSS is the desire to improve the quality of decision-making, for financial, safety or policy reasons. This is true in every sector where there is an obvious disparity in the quality of decision-making made from person to person. Some are designed with the intention of bringing all decision-makers up to the same standard, and others, e.g. DESSAC, (Brooks, 1998) are produced with the intention that the spread of decision-making quality is moved up the scale (see Figure 1.11), which is probably the more realistic approach.

Those who are currently making very good decisions are unlikely to gain much benefit from a decision support tool, especially as it is likely to have been modelled on their own heuristics. Some improvement may however be gained because of the speed and accuracy of a computer-based system. The people who stand most to benefit from the use of a DSS are those whose performance is at the other end of the continuum. Figure 1.11 illustrates the distribution of decision-making quality within agriculture for decisions about the use of fungicides. The majority of people do not make good decisions. Rather than expect all of these people to move to the top, the idea is to help them to move up the scale, to reduce the spread and increase the number of good decisions being made overall.

Figure 1.11: Showing the way in which DESSAC is expected to improve decision-making
1.4 SUMMARY OF THE PROBLEM AND AIMS OF THE THESIS

1.4.1 Summary of the problem

The focus of this thesis is on the development of decision support systems within the agricultural/horticultural industries and in particular those sectors concerned with crop production. The questions which this research will attempt to answer have their beginnings in relatively recent changes in the way in which technology transfer within this industry is organised.

To summarise the discussion in Section 1.1: existing methods of technology transfer from scientific research institutes to the industry were rendered ineffective during a large scale restructuring of government involvement in the industry during the 1980's. The original, simple structure of top down funding by a central administration, feeding a science service (providing the technological advances) and an extension service (translating the science into practice and disseminating it to the industry) no longer exists. The overhaul also resulted in a general reduction in funding available to existing research and extension services and increased competition among them. The main outcome of these changes has been an increase in the value of agronomic information as a tool for generating income, and unfortunately, a decrease in its general availability.

Decision support systems have been seen by many as solutions to the resulting technology transfer problem and an increasing number are being developed. As Section 1.3 suggests DSS have been shown to be useful in other industries i.e. in finance, in medicine and in manufacturing. The crop producer in many ways combines the roles of decision-maker in all of these sectors, they are frequently the MD of their own business, they work with biological systems and they are forced to work within the confines of a fixed and demanding supply chain.

1.4.2 The potential of DSS as a solution

Decision support systems are mechanisms which have the potential to transfer the latest knowledge of plant and pest biology to an industry which is in increasing need of it. DSS
technology can directly address four main issues of concern to the crop producer of the late 1990's, i.e. the need to: increase profits; maintain or improve quality; manipulate crop characteristics; and reduce agrochemical inputs.

**Increasing profits**

Financial pressure is increasing. Small and unprofitable (or unlucky) producers are gradually being swallowed up by the larger and more commercially-oriented concerns (Technology Foresight Panel on Agriculture, 1995). The term 'agri-business' is being used more and more often to emphasise the similarities between the interests of crop producers and those in other manufacturing industries. By enabling the user to fine tune his/her decisions, DSS provide the crop producer with the opportunity to improve the gross margins of a farming enterprise and maximise profit i.e. by more accurately targeting chemical inputs and by more effective forward planning for the use of personnel and machine resources.

**Maintaining quality**

Gross margins are important but for some sectors, particularly in horticulture, the maintenance of quality is more critical (Parker, 1994). Multiple retailers, in response to pressure from the public, insist on a very high standard of quality and uniformity in the fresh produce they buy. The public, it seems, will not tolerate a single aphid or more than the occasional blemish on their vegetables. We, the public, now expect straight carrots of a uniform size and shape and cabbages of a certain dimension. Producers who can meet these requirements secure and maintain some of the most sought after contracts in the business. Because of the size of the multiple retailers share of the retail market for fresh produce, a contract with one of the main supermarkets is valuable and much sought after, and correspondingly the loss of such a contract may be devastating financially. Agricultural DSS, because they incorporate models of pest and disease behaviour, can support the crop producer by giving them timely information about the emergence/appearance and impact of threats to product quality, enabling them to take appropriate action to avoid loss.
**Manipulate crop characteristics**

As the last paragraph suggests, crop producers, particularly fruit and vegetable producers, often need some control over the physical characteristics of their product. Plant breeding efforts over the century have created uniformly producing varieties but other variables can create problems for producers. For example, the marketable head of broccoli can grow from the size of a ten pence piece to something the size of a football in three short days, when the conditions are right. Carrots, if planted too close together, will deform and be worthless, but if spaced a little more generously will produce small and very marketable roots. Seed potatoes sell for several hundreds of pounds a ton and the size of the tuber is a critical component of the profit per hectare. Harvesting too early, before the tubers are of a suitable size, will considerably reduce the value of a crop. Model-based DSS, by providing a better idea of the relationship between a crop and other variables (i.e. physical spacing, temperature, rainfall, etc.) than currently available, can potentially give the crop producer a greater degree of control over the physical characteristics of their product.

**Reduce inputs**

Finally and perhaps most importantly, in addition to being asked to stay competitive, maintain quality, yields and generally stay ahead of the game, the hard pressed crop producer is also under pressure to reduce the level of agro-chemical inputs. The huge increase in yields witnessed in all crops over the last 50 years can be attributed in large part to the use of chemicals. Agrochemicals have greatly lessened the impact on yields and quality due to pests, diseases and competition from weeds, particularly as higher yielding but less resistant varieties have been introduced. In recent years however the environmental and human price of this approach has been questioned. The industry has been hard pressed by its customers, by government and by public pressure to reduce, or at least target more effectively, the use of these products. The industry has responded with a range of self regulatory guidelines (LEAF, NFU protocols, etc.) and the multiple retailers have either joined in or issued their own guidelines (e.g. Tesco’s Nature’s Choice label). DSS can support the crop producer in their efforts to reduce inputs by providing
the information they need to fine tune spray events, i.e. highlighting points when a routine spray is not necessary or when rates applied can be reduced without risk.

1.4.3 The problems with DSS as a solution

DSS, would at first glance, seem to be an ideal solution to the technology transfer problem faced by the crop production industries. Indeed their potential has been recognised for at least a decade and many systems have been developed and distributed both in the UK, in Europe, Australia, New Zealand and in the USA. The enthusiasm with which developers embraced the technology has not however been met with a corresponding enthusiasm by the end users, the advisers, farmers and growers and this is discussed further in Chapter 4.

1.4.4 Research hypotheses and approach

Why is it then, that a technology which appears to offer a great deal to an industry, which has been eagerly approached by many of the scientists as a potential solution to their information dissemination problems, is failing to meet its promise? Is it that the technological base doesn't exist? that the user group are not interested in the science? that the models aren't accurate enough? Or is it that the designers of these systems have fallen prey to the same mistakes made by most isolated groups of technical people in all industries during the early part of a computer revolution i.e. letting the technology lead the design instead of the needs of the end user.

Computer technology made a late entry into the crop production industries. Just over a decade ago there were very few farms using computers for anything, and there was possibly one dedicated farm software company in existence. The developers of DSS were (and still are to a large extent) biologists, or biological statisticians, with an interest in programming. These people are usually untrained in modern software development techniques and methods and have tended to be largely ignorant of the needs of the user group for which they are producing software.
This thesis starts out with a single working hypothesis, that the lack of a formal user-centred design approach is the main contributor to the failure of DSS in this sector. The first part of this research is therefore concerned with examining the evidence to support, or refute, this argument.

Chapters 2 and 3 equate roughly to the 'Method' section in a conventional thesis. Chapter 2 describes the software development methods and tools currently available. These are the methods available to the developer of agricultural DSS, whether they are aware of them or not. This Chapter discusses the strengths and weaknesses of the various approaches in the context of the needs of a crop production DSS project and also of the projects contributing to this thesis. Chapter 3 describes the work which contributed to this thesis i.e. the nature of the projects, the role of the author within them, the methods they employed and the results they obtained.

In Chapter 4 the hypothesis, that the lack of a user-centred design approach is the main contributor to failure of crop-production DSS, is tested. A literature review is used to identify the reasons for the both failure and success of agricultural DSS. The effect that adopting a user-centred design approach might have had on projects which have not succeeded is explored, as is the relationship between apparently successful projects and the involvement of users.

If a user-centred design approach can be shown to be vital to the success of future DSS in this sector then what methods should developers adopt? It is not enough to tell designers they got it wrong, they need to know how to put it right. The second part of this research is concerned with the identification and specification of a user-centred design methodology specifically tailored to meet the needs of DSS developers within this sector.

Commercial software developers now recognise the need to adopt formal methods and there are many available to them. While Chapter 2 highlights the paucity of practical user-centred design methods applicable to small scale development and to DSS in particular, Chapter 5 looks more closely at this problem and examines the specific requirements for a method for DSS developers in this domain. Evidence for a new
approach to task analysis specifically tailored to Decision Support Systems is presented and a flexible method for user-centred DSS design is proposed.

The final part of this thesis is concerned with the development of the user interface. The user interface is a critical component in most software systems and particularly so for crop production DSS, for reasons which are dealt with elsewhere in this document. In addition to a methodology for user-centred design, the thesis proposes a means of identifying and collating guidelines specific to the development of the human computer interface. Interface features developed for two of the contributory projects are used as examples.

In Chapter 7 the thesis is summarised and its contributions to technology transfer in crop-production, DSS science and Human Factors are discussed. The chapter also examines the future of DSS in crop-production and describes the main outstanding research questions highlighted by the research.
2.0 SOFTWARE DEVELOPMENT: METHODS AND TECHNIQUES

This aim of this chapter is to provide the background for the choice of methods, tools and techniques available to software developers in crop production and employed in the research described in Chapter 3.

The context in which software development takes place is complex and some explanation is required to make the structure of this chapter more meaningful. There are five main sections: stages of development; models of development; methods of development; tools and techniques; and finally a discussion of the approach adopted within this research. The description of development stages is required to show the ways in which the models of software development differ from one another; models being characterised by the arrangement of and iteration between stages, and what they consider and don’t consider. In turn a description of models of software development is necessary to highlight the ways in which methods differ from one another, as methods are usually based on one model or another. Finally the methods, tools and techniques available to system developers and their advantages and disadvantages are described. This provides background for the discussion of the methods and tools employed in the contributing projects (Chapter 3.0) and proposed for use by DSS developers (Chapter 5.0).

2.1 SOFTWARE DEVELOPMENT TASKS

Although there are many methods and models for software development, they all recognise a basic set of development tasks (distinct areas of activity). Each method or approach defines its own sub-divisions and ways of organising these tasks over time. Most however recognise functionally equivalent task activities which can be generalised and labelled as ‘planning’ ‘design’, ‘development’ and ‘support’. The emphasis placed on these tasks and the degree to which they are broken down into sub-tasks may differ widely as Table 2.1 indicates, using examples from three different approaches:
Table 2.1: Labels given to software design tasks by SSADM\textsuperscript{7}, DSDM\textsuperscript{8} & OOADA\textsuperscript{9}

<table>
<thead>
<tr>
<th>Method</th>
<th>SSADM</th>
<th>DSDM</th>
<th>OOADA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Feasibility</td>
<td>Feasibility study</td>
<td>Conceptualisation</td>
</tr>
<tr>
<td></td>
<td>Problem definition</td>
<td>Business study</td>
<td>Analysis</td>
</tr>
<tr>
<td></td>
<td>Problem identification</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>System analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Analysis of system/problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Requirements specification</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Selection of technical option</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>System design</td>
<td>Functional model iteration</td>
<td>Design</td>
</tr>
<tr>
<td></td>
<td>Data design</td>
<td>Design and build iteration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Process design</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physical design</td>
<td>Design and build iteration</td>
<td>Implementation</td>
</tr>
<tr>
<td>Development</td>
<td></td>
<td>Implementation</td>
<td>Evolution</td>
</tr>
<tr>
<td>Support</td>
<td></td>
<td></td>
<td>Maintenance</td>
</tr>
</tbody>
</table>

A more detailed generic description of software development tasks is given by Preece (1993) and reproduced in Figure 2.1. Preece’s classification contains most of the task labels commonly employed in development methods and has therefore been used to structure this section. The nature of these tasks is discussed in sections 2.1.1 to 2.1.9. It should be noted that proportionately more emphasis is placed on the user requirements and evaluation/validation tasks as these relate most directly to the subject of this thesis. While it can be said that human factors contributions can be made to most stages of the software development process, it is true that the major impact is felt in the areas of requirements and system evaluation.

\textsuperscript{7} SSADM – Structured Systems Analysis and Design Methodology (see Section 2.3.2)

\textsuperscript{8} DSDM – Dynamic Systems Development Method (see Section 2.3.4)

\textsuperscript{9} OOADA – Object Oriented Analysis and Design with Applications (see Section 2.3.5)
2.1.1 Project selection

This goal of this task is to make a suitable choice of project, one which appears to be feasible and cost-effective. In some cases the choice is obvious because it is the outcome of a planned series of products or the end result of a piece of research (or it is determined elsewhere). However it is more likely that the task in most software houses and in-house software teams is to choose between several, equally interesting, or potentially profitable projects. The completion of this task will result in a project definition as shown in Figure 2.1.
2.1.2 Feasibility study

Projects should always include some kind of feasibility study to ensure that the project idea is attractive to the intended users, useful enough for them to justify investment (cost and effort) and will not cost more to develop and support than the likely return. The return on investment may not just be financial in the case of an in-house team, but will be the return in productivity or satisfaction on the part of the users. The output from a feasibility study may be used to feed into the selection process in terms of the cost-benefits of particular options. A seemingly good idea for a product may turn out to be too expensive for the potential market to support or may simply be a case of 'technology looking for a solution'. The output of this task will be a feasibility report.

2.1.3 System analysis

This task often occurs in tandem with a requirements analysis (where one is conducted) and shares data with it and the feasibility study. This is the first pass at defining the requirements for the system. A high level statement of requirements may be issued at the end of this task i.e. at the level of 'the system must be capable of taking data from an Access database.'

2.1.4 Requirements analysis

This is the task which is traditionally considered to fall within the domain of the human factors specialist and which has been rather neglected by others in the software development business. However a need to change this attitude has been recognised, partly due to research which suggests that the cost of errors in the requirements task is much higher than that of errors made in other task phases (e.g. Boehm, 1981). Jirotka & Goguen (1994) for example estimate that errors in this task may account for something like 50% of the total cost of debugging. Andreasson (1990) suggests that the ratio of costs for putting mistakes right rises from 1:10:1000 as the product moves from concept design to production. These findings coupled with the need to produce marketable products, to time and to budget has generated considerable interest in creating methods to ensure that this process is rigorously carried out.
Requirements are aspects of the system which need to be included in the system design and the function of the requirements analysis task is to identify them. Two broad models lie behind the methods for requirements capture, the first assumes that an ideal system exists and that the aim of the method is to uncover its functions. This can be likened to the approach of sculptors like Michaelangelo who said that their task was simply to remove the unnecessary pieces of stone to reveal the perfect form beneath. The second school of thought suggests that there is no system until it is ‘negotiated’ (McDermid, 1994) gradually as part of the elicitation process. In this model there are many potential outcomes to the requirements process and no single ‘right’ path. The system evolves as a result of an intermingling of technical ideas, user and organisational needs and limitations. In many cases the requirements emerge after the first prototype as users and designers become more aware of the possibilities offered by the system (Harker & Eason, 1990). This is analogous to the sculptor who works with the material, applying a design but also making use of the inherent structure as it emerges, to create something which could not have been specified in advance.

The output of this task is a requirements specification, a document which can be used as a communication tool between the user and the developer. McDermid defines a good requirements specification as one which:

"says everything which the designer needs to know in order to produce a system which satisfies the customers/users - and nothing more." (McDermid, 1994, p22).

Many requirements documents, constructed by those from the ‘softer’ side of the sciences and not in tune with the precision employed by software engineers, have tended towards the wordy and vague. These documents, while packed with useful information, are not easy to reconcile with the rest of the design process, characterised by logic, code, flow diagrams, etc. If it is hard to incorporate such a specification into the design it is even harder to check that it has been adopted. Many of the new methods and tools, in recognition of this problem, explicitly provide ways in which requirements can be documented and traced throughout the design process.
The requirements specification document can take a number of forms. Many earlier ones are free form and written in natural language. The more recent style is still natural language-based but includes mechanisms for numbering and tracing the process of the requirements during design and implementation (e.g. STARTS Handbook, NCC, 1989). Another form is adopted by those who really wish to pin the requirements down in technical language, where the whole specification is written in a formal language such as Z (Spivey, 1989), see Figure 2.2. Each method has its benefits. The looser forms allows for flexibility but the formal methods provide clarity and traceability.

\[
\begin{align*}
\Delta \text{FleetSeatAllocation} \\
f?: \text{FLIGHT} \\
s?: \text{SEAT} \\
p?: \text{PERSON} \\
\text{f? \in knownFlights} \\
\text{f? \in dom allocation} \\
\text{f? hasSeat s?} \\
\text{s? \notin dom allocation f?} \\
\text{allocation' = allocation \oplus \{f? \mapsto allocation f? U \{s?\mapsto p?\}\}} \\
\text{knownFlights' = knownFlights} \\
\text{hasSeat' = hasSeat}
\end{align*}
\]

Figure 2.2: Booking a seat on a plane. Example of Z notation (Lightfoot, 1991. P124)

The contents of the requirements specification will normally contain functional and non-functional requirements. Functional requirements relate to the scope of the system, the functions to be performed, and a description of the data and the structure of the data to be processed. In its detailed form a functional requirements specification describes:

- Normal functioning, inputs, outputs, operation and control.
- Abnormal functioning, exceptions etc.
- Dependability properties e.g. safety and security.
- Performance e.g. throughput.
- Quality e.g. maintainability or modifiability.
• Expected changes e.g. likely modifications to interface devices (McDermid, 1994. p24)

Non functional requirements are those things which aren’t specifically ‘functional’, i.e. performing a function, but are nonetheless important i.e.:

• Look and feel, e.g. the standard for its appearance and mode of operation.
• Usability, e.g. the ease with which it can be used and learned
• Performance, e.g. the speed and accuracy of the system.
• Maintainability, e.g. the ease with which the system can be maintained
• Security, e.g. the level of security and integrity required.
• Political aspects, e.g. avoiding conflict or maintaining an organisational stance
• Legal aspects, e.g. ensuring compliance with legal requirements

2.1.5 System design

Requirements emerging from the requirements task feed directly into the system design, in one phase or in increments depending on the model adopted (see next section). The system design task and the detailed design task may be one and the same thing in smaller projects. At the larger end of the scale the system may be too big to be designed in a single pass. In the DESSAC example (described in Section 3.4) the initial system design focused on the broad design of the various system components. It described the way in which the components would link and communicate with one another. A large project has to make decisions at an early stage concerning the model it wishes to follow and the type of technology it is going to adopt. These design decisions then make it possible to concentrate on the detailed design.

2.1.6 Detailed design

The purpose of this task is to determine the actual form of the various components and mechanisms. The system design document may stipulate that component A and component B will communicate using a protocol of type X. The task here is to specify exactly how this will be achieved and may be documented by using a design language, flow charts or plain text.
2.1.7 Implementation

According to the Preece model there are three identifiable implementation tasks:

**Construction**

Producing the actual code, computer recognisable or compilable instructions.

**Testing**

There can be several parts to the testing task: unit testing in which each path within each module is tested; function testing where the function is tested within the modules in which it operates; and component testing where some or all of the components of a piece of software are tested together (Whitten, 1995). Testing at this level refers to testing of the code to ensure that the code performs as defined in the design specification. Alpha and Beta are names given to pre-release testing tasks, Alpha testing is generally carried out 'in-house' whereas Beta testing often involves volunteer users.

**Sign off**

Sign off is the process by which the code, function, component or full system is classified as complete.

2.1.8 Validation and verification

In Figure 2.1, this task is shown to be linked to the requirements analysis, systems design, detailed design, implementation and maintenance tasks. This is a description which would not be true of all methods because it implies continual reference to the source of the requirements i.e. the users. The function of this task differs from implementation testing in that it is not the robustness and fit to design specification that is being checked, it is the design specification itself. Validation is the process of checking that the product conforms to the client's requirements and verification is the process of checking that the requirements were accurately represented (Preece et al., 1994, p357). The Preece representation suggests that as soon as there is some formalisation of requirements, or a prototype or other functioning part of the system, it should be tested for fitness with stakeholders.
Usability Evaluation is part of this process but is often described separately from it, perhaps due to its origin within the Human Computer Interaction field of interest rather than from software developers or computer science. Usability is defined by Preece et al as:

‘a measure of the ease with which a system can be learned or used, its safety, effectiveness and efficiency, and the attitude of its users towards it.”. (Preece, 1993, p131),

In the section above usability is listed as one of a number of non-functional requirements. In its broadest sense however it can be seen to encompass functional and non-functional requirements alike. A system is only truly usable if it provides users with the functionality they need, the look and feel most compatible with the user and user’s task, the performance and maintainability required, an appropriate level of security and if it conforms to political and legal aspects of operation. Deviations from these requirements are reductions in usability.

There are many tools and techniques for validating, verifying and evaluating system software and specifications and these are discussed later in this section. The output from these methods is most often a written report which may be accompanied by video or statistical evidence of specific problems.

The validation task continues after the release of software as part of maintenance when feedback from the final users of the software is fed back into future developments.

2.1.9 Maintenance

This is a critical task which is not often mentioned in design methodologies and yet which can be one of the most significant costs to a software developer, particularly of software which contains data or material which ‘ages’ and becomes out of date. Software needs maintenance in a number of ways.

*Bug-fixing:* it is a rare system which emerges from the development process free of ‘bugs’ or coding errors and indeed, many purchasers believe that some suppliers wait for
the end user to do the bug-finding for them as a cost saving measure! Most developers will need to re-issue the software after bugs have been fixed.

Product enhancement. As well as spotting coding errors, users often suggest ways in which the product could be improved. Keeping a product ‘fresh’ and ahead of competitive items in the market is important to a software company.

Updating. Some products contain information which becomes ‘dated’, for example encyclopaedias, product databases and catalogues. These will need to be re-issued on a regular basis to keep them up to date.

2.2 MODELS OF SYSTEM DEVELOPMENT

Not all of the tasks mentioned above are described in every software development method. The order in which they are arranged and applied is usually defined by the process model adopted. These models for development often emerge from the particular circumstances and experience of their developers and the domains in which they normally operate, and may therefore be more or less transferable to other situations. A variety of models and variations are available to developers but the most common ones are: code-and-fix, waterfall, incremental, iterative and spiral and these are described below.

2.2.1 Code-and-fix model

This model is the oldest and simplest of all the models (Whitten, 1995). It requires little in the way of advance planning; coding begins almost immediately. After a certain amount of coding the product is tested, the errors corrected, and coding continues. The coding and testing cycle is repeated until the product is fully developed and delivered to the customer.
It is suggested (op cit.) that this method is suited to small and simple projects. The absence of a planning or a formal development style is likely, however, to result in a lower quality of product than that produced under the other models and the product may be harder to maintain because of a lack of planning in the design task.

2.2.2 Waterfall model

The name of this model is derived from its appearance i.e. as tasks are completed one after the other. Figure 2.4 illustrates the approach, the dotted arrows indicate feedback loops which are employed whenever there is a need to revisit an earlier stage. Although the arrows indicate that a return is only possible to a previous stage, the model does allow a return to any of the preceding stages. Whitten suggests that this model is best suited to
medium and large sized projects with well defined requirements. It is hard however to think of any project of that scope in which requirements can be well defined in advance.

### 2.2.3 Incremental model

The incremental model is very similar to the waterfall model, but in the incremental model the product is developed a piece at a time i.e. incrementally. As figure 2.5 indicates, the requirements, definition and high level design are completed and documented and then each piece is developed according to a pre-defined master plan. As each piece is completed it is tested and added into the final system. This method is quite popular in software design houses as pieces of the final product can be developed in parallel to one another. The overlapping allows code to be developed early in the process and permits developers to provide early versions to clients for testing and comment. Unfortunately this method becomes very hard to manage as the size of the software product increases.
2.2.4 Iterative model

This model can sometimes be confused with the incremental model. However, in contrast to the incremental model, where a fully designed system is developed in stages, the iterative model development begins before a full design is available. The product is developed up to a point and then refined as new requirements become apparent. Each iteration is the basis for the next iteration.

This type of model is said to be best suited to situations where the requirements and product definition are not well understood, for example in innovative or futuristic systems. In these cases there is often a need to develop something that will give the potential users a feel for the product, then they can provide a more refined statement of their requirements for it. The iterative model provides the flexibility to adapt to changing requirements, something which the incremental model can not do very easily.

A variation on the iterative model proposed by Harrison (1992) is described by Preece et al (1994, pp359). In this model a single phase of design and build tasks is undertaken, resulting in a prototype system which is tested with users. Based on the results of the testing the requirements are fixed and the process then follows a direct development route. The advantages of this model, it is suggested, are that it costs less than approaches...
which require more than one iteration, and that it helps to define user requirements and to control the project.

Figure 2.7: The ‘W’ model of system development (Harrison, 1992, from Preece et al, 1994 p359)

2.2.5 Spiral model

The Spiral model was developed by Boehm (1988) in response to the problem of management and control of the software development process. The method is clearly
iterative and uses the same idea of developing an early prototype in order to get a clearer idea of the requirements for the final system. Unlike the iterative model however, this prototyping stage is clearly defined and the spiral model includes a period of risk analysis at each stage. In risk analysis the project looks to identify those components which are at the highest risk of being wrong, or being very costly to correct.

2.2.6 Star model

The STAR model (Hix & Hartson, 1993) was derived as a result of analysing actual design practice among HCI designers by its developers.

![Figure 2.9: The star life cycle (Hix & Hartson, 1993)]

In the star life cycle (see Figure 2.9) development may begin at any stage (entry arrows) and may be followed by any other stage (double headed arrow). In this approach the requirements, design and product gradually evolve and become increasingly well defined.

2.2.7 Discussion of models

The main differences between the models above is the extent to which they see the process as an orderly flow from one definable stage to another and the extent to which they permit iteration between these stages. At one end of the continuum is the waterfall
model in its pure form, it is very orderly in its progression and does not contain any intentional means of returning to previous stages. A later version described above, and probably all practical implementations of the model, includes iteration between any stage. At the other end of the continuum is the Star model which admits to no prescribed order at all and is very iterative. The other models, containing various mixtures of order and iteration, all fall into place between them. While most of the models are defined as a means of providing an external control on the development process the Star model is the only one of those described above which is explicitly modelled on actual design practice. As real life has a tendency to warp or mutate the best laid plans it could be argued that Star, by starting from a realistic perspective, offers the most useful model on which to base a method.

2.3 DIFFERENCES BETWEEN METHODS

There are an enormous number of software development methods available to the software project manager, far too many to describe here. There are however a smaller number of categories into which they seem to fit, these categories relate to their description as 'structured' (to differentiate them from earlier 'unstructured' methods), their status as 'hard' or 'soft', and their applicability for large scale systems or for smaller rapid application development (RAD). Another group of methods belongs to the object oriented (OO) school, OO methods are also structured but have very different notions of coding behaviour and are therefore usually treated separately. This section will examine the main focus of each of the method 'schools' and use examples for illustration.

2.3.1 Structured methods - general

Structured design approaches were initiated in the late 1960’s when it became apparent that the existing methods were inadequate for the growing needs of the defence and data processing industries (Parsons, 1997). They are typically 'top down' i.e. starting off with a high level set of objectives and working down in detail towards the solution. There are two traditional approaches to 'partitioning' these objectives or requirements, the process driven approach, or 'functional decomposition', and the data driven approach or 'data
decomposition'. In functional decomposition the problem is decomposed into its constituent processes, each of which should be a coherent and simple module. This is the start point for many commercial methodologies, which are function & process-oriented. The data within the system is spread across the system in the functional approach, without any logical organisation whereas in the data driven approach the internal structure of the data is used to organise the processes that take place. Both approaches are said to present problems which the object oriented approach described below attempts to overcome. A third technique is called 'traditional', an example of which is the NCC approach in the UK (Curtis, 1989) NCC is focused on the translation of an existing system into a computerised system without improving it in any way and will not be discussed further here.

2.3.2 'Hard' structured methods

Hard system approaches see software development as a very 'clean' activity without soft or woolly edges - hence the label 'hard' methods. There is a basic assumption that there is a clearly identifiable existing system which simply has to be documented, and that there is a clear and agreed statement of the objectives of the analysis and design. They also all assume that it is possible to measure objectively whether the system meets its objectives.

Examples of hard systems methodologies are described briefly below.

**Structured Systems Analysis and Design (SSAD)**

SSAD was one of the first structured 'methods' and is essentially a set of tools for the analysis and design of computer systems and not a method as such. The objectives of the tool-set were to:

- provide better communication and less confusion between analysts and end users
- ensure a high degree of precision in specifying solutions
- reduce confusion in the analysis task by developing a structured output which would be easier to explain and to work out subsequently.
improve communication, reduce the number of faults in program design, produce structured self documenting computer codes which would be easier to maintain.

It uses a structured approach based on tools, such as data flow diagrams, which allow the analyst to take a high-level view of tasks and their associated data and progressively decompose them in a structured manner. The widely used flow-diagramming method IDEF0 was derived from this tool-set (Marca & McGowan, 1988).

Structured Systems Analysis and Design Methodology (SSADM)

SSADM is one of the most widely used application development methods in the UK, and increasingly adopted in Europe and internationally as well. It is a prescriptive methodology, reflecting the waterfall approach, which specifies all tasks and their sequence in detail. The overall objective is ultimately to produce a detailed data and program specification for a computer system in a standard format by applying standard techniques and procedures. The latest version of the method (SSADM4+) describes a framework, known as the System Development Template (SDT), for the capture of user requirements, the analysis of information needs and the design and specification of information systems. (McLaren et al., 1991)

Yourdon Structured Method (YSM)

YSM is a commercial structured systems design method. It is used at the analysis, design and implementation stages of the systems development life cycle and follows a ‘waterfall’ approach. The method uses modelling techniques to view the three main characteristics of any system i.e. data, dynamics and process. The method attempts to prescribe a software solution which will include both computerised and manual systems. YSM is designed to encapsulate all manual and mechanised actions currently used or projected in terms of transformation, structure and time sequence behaviour (Yourdon, 1998).

Jackson System Design (JSD)

JSD is a proprietary system design methodology. JSD models entities in a problem domain and maps them onto tasks; the functions of the systems are added later. The
method uses Entity Structure Diagrams and JSD network diagrams to show tasks and interfaces between them. There are essentially six steps and three stages to the method.

**Information Engineering (IE)**

The Information Engineering approach is an example of a data-driven waterfall approach. It is designed to provide structured support for the development of information systems. It consists of three main tasks, analysis, design and generation and a strategic planning. The main outputs of the process occur in the analysis stage are different levels of data models, termed strategic, tactical and operational data models.

**2.3.3 'Soft' systems design methodologies**

The participative, user-centred, or 'soft' approach differs from the hard approach in a number of ways:

- Recognition that technical systems cannot be treated independently of the social systems in which they are embedded and with which they interact.
- The social system within which the work occurs must be as much subject to scrutiny and design as the technical system.
- The knowledge and experience of current users is seen as very valuable in design.
- User participation in analysis and design is essential as it reduces fears over the introduction of new technology.
- Ethical commitment to the belief that users have a right to have their say over the design and operation of a system.

In short where hard methods focus on system functionality i.e. what the system is intended to do, soft methods deal more with 'non-functional requirements' e.g. usability and compatibility with organisational structures. A discussion of this approach follows.

**What is user-centred design?**

User-centred design, as its name suggests, refers to design methods where the users are the focus of the design activity and their needs are taken into account in all design and development tasks. Also known as 'participatory design', the phrase 'user-centred
design’ was first coined by Norman (Norman, 1983) as a means of describing his approach to user interface development.

One of the goals of those who adopt a user-centred approach is an improvement in the ‘usability’ of the final product (see section 2.1.8 for a definition) through the involvement of the end user in the design process. The user can be defined as anyone who has a stake in the system (stakeholder), and this may include those:

- who are paying for the system.
- who commission the system.
- operating the system.
- who, actively, or by default, decide where, and how, the system is actually used.
- who are accountable for the work to which the system contributes.
- whose work is affected by the system.
- whose life is made better by the system.
- who have to learn new skills, or whose old skills are made obsolete.
- whose life is made worse by the system.
- to whom the system delivers outputs.
- from whom the system gets inputs. (Knight, 1989)

It should also include the broader needs of the organisation in which the system will operate, i.e. needs which may not be explicitly stated by any one individual but held in common by all.

What is good about it?

Adopting user-centred or participatory design is said to have several benefits. Benefits to the designer are said to be:

- access to more accurate information about the tasks and problems that users face and must perform or solve;
- and the opportunity to explore alternative design decisions and select interface approaches and designs based on what works best with the users.
For the users, participating in the design provides a sense of ‘ownership’ and a feeling of investment in the system. It is suggested that users and their managers who participate are more likely to support the system during important system test cycles. (Schneiderman, 1987)

**-How does it work?**

Preece (1993) suggests four principles for user-centred design:

1. Focus on the users and the users’ needs, and in so doing make user issues rather than technical considerations central in the design process.

2. Carry out a task analysis in which details of the users’ tasks and information about the task environment are collected, so that the users’ needs are well understood. Task analysis needs to be done in addition to a general requirements analysis, which tends to focus on what functionality is required rather than how to provide that functionality.

3. Carry out early testing and evaluation with users to ensure that the system is designed to meet their needs.

4. Design iteratively with many cycles of ‘design-test-redesign’. Do not expect to produce one ‘right’ solution which is not changed, but instead aim to design an evolving system which is tailored more to users’ needs with each iteration, and which will be able to accommodate future changes (Preece, op cit. p42).

**Iteration**

Iteration is a fundamental component of user-centred design, one of the ‘principles’ outlined by Preece above. Iteration refers to the process of repeating stages of the design cycle. In a user-centred design approach this is a way of ensuring that users can get involved in design during repeating phases of design-test-design. Iteration, as a means of incremental refinement, is also used in non-user-centred models and methods. This approach also overcomes the inherent and critical defect that users, being inexperienced
in system design, may not be able to express their requirements adequately at the beginning.

The following are examples of soft systems methods:

**Soft Systems Methodology (SSM)**

The SSM methodology was originally developed by Peter Checkland at Lancaster University (Checkland, 1988) but has since evolved. It was designed to allow the human element of managerial systems to be incorporated in system design work but can be applied to many other situations. It describes itself as a systemic, and user-centred approach to problem-solving. It has seven stages but these are not intended to be followed in any given order.

Soft Systems methodology can be applied to any situation or problem but is most appropriate for the analysis of systems that are not well defined. As it does not formally specify communications structures, roles or responsibilities it is perhaps best applied in situations where these things already exist or in conjunction with a more formal project management method. Its key strength lies in defining the situation in which a problem lies rather than in finding a solution to that problem and as such is best applied at the start of a user-centred design approach (Checkland, 1988).

**Effective Technical and Human Implementation of Computer-Based Systems (ETHICS)**

This methodology has been designed and developed over a number of years by Enid Mumford of the Manchester Business School, UK. It is based on the joint philosophies of socio-technical design and participation and as such is not specifically related to computer systems. ETHICS is intended to provide users with the means to take control of systems' analysis and design. It does this by involving them in the process of analysis and providing them with the means to analyse requirements and design the system from an organisational perspective. It also provides the design team with a means of trading off social and technical features of the design to ensure an 'optimised' socio-technical
outcome. It is a description of a process rather than a collection of tools and techniques and does not address technical issues.

The objectives of the method are to:

- Enable future users of a new system to play a major role in its design and to assume responsibility for designing the organisational context of the technical part of the system.
- Ensure that new systems are acceptable to users because they both increase user efficiency and job satisfaction.
- Assist users to become increasingly competent in the management of their own organisational change making it a shared activity with technical specialists.

ETHICS is very useful for improving communication between analysts and users, collecting useful information from analysts, encouraging users to play an active role, identifying training needs, designing end user jobs, and improving the social working environment of users. It may be too complex and costly for use in small scale projects and too time consuming for Rapid Applications Development (RAD) projects but is very economic to install.

ETHICS is not designed to produce a technical solution, its purpose is the optimisation of social and technical aspects of a complete system.

It is generally used to assist the process of computer system development especially where the participation of users in the design process is seen as particularly critical to the effectiveness of the system outcome. The most usual application area is a complex, office-based system at the departmental level where there is a large component which does not lend itself to automation. It can handle both structured and unstructured tasks (McLaren et al., 1991).

**Open System Task Analysis (OSTA)**

OSTA (Eason, 1988; Eason & Harker, 1989) is a socio-technical systems analysis model in which technical requirements (the systems structure and functionality) are specified alongside social system requirements (usability and acceptability). Its underlying aim is
to provide a methodology for understanding the transformation that occurs when a computer system is introduced into a working environment. Systems analysis is used to explore organisational issues as well as traditional flows and key tasks. After this socio-technical solutions involving the identification of technical and social constraints are identified. Information collected from these methods is communicated to the design team in the form of flow charts and descriptions written in ordinary language.

**Multiview**

MULTIVIEW (Avison & Wood-Harper, 1990) is a prescriptive approach to user-centred design. It is specifically an information systems design methodology which combines a number of approaches into a staged, controlled methodology (see Figure 2.10).

![Multiview Methodology](image)

**Figure 2.10: Multiview methodology (Avison & Wood-Harper, 1990)**

Multiview was designed to provide direction for systems designers because it specifies an order in which certain activities should be carried out.

**The STAR approach**

The STAR approach is based on the STAR model described earlier in this section and it takes the idea of prototyping and evaluation much further than many other approaches. Evaluation is central in this method. All aspects of systems development are subject to
constant evaluation by users and by experts. The model also promotes an 'alternating waves' or incremental approach to systems development; it recognises that the traditionally preferred 'top down' approach needs to be complemented by a 'bottom up' or synthetic approach. The star life cycle stresses rapid prototyping and an incremental development of the final product.

**Usability Engineering**

Usability engineering was defined by Tyldesley (1988) as a 'process whereby the usability of a product is specified quantitatively, and in advance. Then as the product is built it can be demonstrated that it does or does not reach the required levels of usability.' The components of usability were later operationalised by Shackel (1990) so a product could be tested in this way. The semi-scientific and engineering nature of this method has led to it being well received in a number of companies because it provides a systematic procedure for testing the usability of a product during development. The underlying aim of usability engineering is to engineer for improvement. The design and evaluation components of usability engineering are very closely interrelated in cycles of design-evaluate-redesign. The engineering nature of the process is reflected in the iterative development and the fact that many characteristics of a product are specified quantitatively and in advance. Testing usually takes place in a purpose-built laboratory and follows a procedure that is broadly scientific in nature.

Usability engineering is less a generalised system design method than one approach to adopt within one or more, more general methods.

**The ORDIT approach**

The ORDIT methodology (Dobson et al., 1994) was created within an Esprit II project by Algotech srl, HUSAT Research Institute, The MARI Group Ltd., the Computing Science Department of the University of Newcastle and the Work Research Centre. The ORDIT method takes a socio-technical approach and places the system within its broad operational environment, with the user as an integral part of the system. Its central tenet is that design methods appropriate for technical systems cannot simply be applied to
socio-technical systems and that in fact most previous methods have ignored the importance of organisational issues in the design of IT products.

The aim of the ORDIT methodology is to support system designers in reasoning about organisational goals, policies and structures, the work roles of end users. This enables designers to identify and express the organisational side of user requirements. ORDIT is not a complete systems development methodology but a set of tools to apply within any structured method to ensure that the organisational issues are not neglected.

2.3.4 Rapid Application Development (RAD)/Prototype methods

RAD or Rapid Application Development is a response to the increasing pressure within certain sectors to deliver new IT products in a short space of time i.e. weeks or days. RAD can be seen as another sub-section of the 'structured' methodologies and is characterised by:

- Prototyping (evolutionary rather than throw-away)
- Development workshops (Joint Applications Development)
- Timeboxing (strict limit placed on activities)
- Structured Walkthroughs (peer review of prototypes)
- SWAT (Skilled With Advanced Tools) teams

In many ways RAD appears to be a hybrid of hard and soft approaches, with a strong focus on system functionality i.e. what the system is intended to do, and also on the involvement of users to enshrine 'non-functional requirements' e.g. usability and compatibility with organisational structures.

Prototyping is the core of the process, and is used to identify weaknesses in understanding. Unlike earlier methods which stressed the use of throw-away prototypes, RAD makes use of visual languages to build prototypes which can be incrementally developed into the final system. Workshops are used instead of face-to-face meetings. Initial scoping interviews are carried out but most of the work is done within workshops. Workshop participants are all those (or representatives) who are affected by the system.
and those who have the power to make decisions (power and knowledge). During the workshop decisions about prototypes, timescales and team membership are taken.

This face-to-face approach is felt to alleviate much of the 'blocking' or resistance to change which can take place when new systems are developed and it provides the system with champions. The aim of the method is to produce only that which meets the requirements and nothing more.

**Dynamic Systems Development Method (DSDM)**

The Dynamic Systems Development Method (DSDM) is a public domain Rapid Application Development (RAD) method (DSDM Consortium, 1996) which has been developed by a consortium of vendors and user organisations. It is considered to be the UK's de-facto standard for RAD.

A fundamental assumption of DSDM is that nothing is built perfectly first time, but that a usable and useful 80% of the proposed system can be produced in 20% of the time it would take to produce the total system (the other 20% being addressed in later iterations). DSDM provides a generic process which must be tailored for use in a particular organisation dependent on the business and technical constraints. It consists of five main tasks: feasibility study; business study; functional model iteration; design and build iteration; implementation. It is based on nine principles which are applied as appropriate in the various parts of the method. These principles are:

- **Active user involvement - user involvement is imperative.**
  DSDM is a user-centred approach. As argued earlier in this chapter, adoption of a user-centred approach is important to successful design. In DSDM users no longer sit outside the development team acting as suppliers of information and reviewers of results but are active participants in the development process.

- **DSDM teams must be empowered to make decisions**
  DSDM teams consist of both developers and users. These teams must be able to make decisions as requirements are refined and possibly changed. They must be able to agree that certain levels of functionality, usability, etc. are acceptable
without frequent recourse to higher level management. While specifically created to meet a RAD need, application of this principle would free up resources and speed progress in any project.

- The focus is on frequent delivery of products.
  A product-based approach is more flexible than an activity-based one. The work of a DSDM team is concentrated on products that can be delivered in an agreed period of time. While this principle is most applicable to RAD, regular delivery of prototypes can also improve non-RAD developments by providing feedback points.

- Fitness for business purpose is the essential criterion for acceptance of deliverables. The focus of DSDM is on delivering the business functionality at the required time. The system can be more rigorously engineered later if such an approach is acceptable. Traditionally the focus has been on satisfying the contents of a requirements document and conforming to previous deliverables, while losing sight of the fact that the requirements are often inaccurate (and become more inaccurate with the passage of time) and the previous deliverables are flawed. This is another principle which is much more broadly applicable. No project should lose sight of the fact that the system is being designed to meet a business purpose; while the goals may remain constant, the context (and therefore the constraints) may well change.

- Iterative and incremental development is necessary to converge on an accurate business solution
  DSDM allows systems to evolve incrementally. Therefore developers can make full use of feedback from the users. Iteration is inherent in all software development. DSDM recognises this and, by making it explicit, strengthens the use of iteration. Models which incorporate iteration are more likely to succeed as discussed in the earlier section on models.

- All changes during development are reversible
  Backtracking is a feature of DSDM. However in some circumstances it may be easier to reconstruct than to backtrack. This may be an easier feature to adopt in
RAD than in other developments but where possible could usefully be adopted, depending on the nature of the change and the environment in which it was made.

- Requirements are baselined
  Baselining high-level requirements at a high level means "freezing" and agreeing the purpose and scope of the system at a level which allows for detailed investigation of what the requirements imply. Further baselines can be established later in the development. All good projects should start with a baseline of requirements to prevent lower level requirements growing beyond the ability of the project to deliver.

- Testing is integrated throughout the life-cycle
  Testing is not treated as a separate activity. As the system is developed incrementally, it is also tested and reviewed by both developers and users incrementally to ensure that the development is moving forward not only in the right business direction but is technically sound. Early in DSDM, the testing focus is on understanding the business needs and priorities. Towards the end of a project, the focus is on assuring users and developers that the whole system operates effectively. A principle which needs no adaptation to be applicable to any project.

- A collaborative and co-operative approach between all stakeholders is essential
  In DSDM and in other small-scale projects this means that all the parties, users, management, system developers etc., have to recognise the flexible nature of the process and the importance of meeting the stated objectives by the target date. A collaborative approach does place a great emphasis on communication as everyone needs to be kept informed. In the small autonomous DSDM group communication can be largely verbal. This type of approach in large scale projects requires considerable management and written documentation.

There are key criteria that a system should demonstrate for DSDM to be applied easily. The application should have the functionality reasonably visible through the user interface (screens, reports, etc.) to enable prototyping to be used to maximum benefit. The project should be able to identify all classes of users who will use the end result so
that knowledgeable representatives can participate throughout the life of the project and provide coverage of the views of all the user classes. DSDM calls these representatives "Ambassador Users" as they operate in much the same way as diplomatic ambassadors by providing a two-way communication channel between the business community and the IT community. If the system is large, it should be able to be broken down into smaller components or modules either for incremental delivery or for development by parallel teams. There are other more detailed selection criteria contained in the DSDM Suitability Filter.

2.3.5 Object oriented methods

The premise of an Object Oriented (OO) approach is to manage the complexity of the real world by reducing it to a description of objects, their functions and the relationships between them. The world in an Object Oriented method is seen and modelled as a system of collaborating objects. Compared with the traditional software lifecycle the OO lifecycle dedicates more time to design (analysis and design) and less time to implementation and testing (when an OO programming language is used).

It has been said that the main difference between an OO method and a structured method is the fact that the OO approach is not based on functional decomposition but on describing the real objects that play a role in the real world. The benefits of an Object Oriented approach are said to come from a greater emphasis on the properties of an Object, which forces the developer to think more carefully and deeply about what an Object is and does. The main cost benefit of using an OO approach is not found in a reduced development time but in future re-use of proven Classes/Designs with reduced errors and maintenance efforts.

In general OO methods are not sequential and they place great emphasis on the ability to re-use solutions. The focus on objects allows developers to re-use concepts and solutions for the same object in different circumstances. It is suggested that the OO methods improve analyst and problem domain expert interaction although they still prescribe a passive role for the user. The Object Oriented approach is based on an underlying
representation (Classes and Objects) which, according to Coad & Yourdon (1991), leads to the following improvements on a structured approach:

- Removal of the difference between analysis and design notations
- Removal of the 'transition' from analysis to design
- Avoidance of the difficulties of the waterfall model and support for spiral and incremental development
- Continued requirement for the skills and strategies of analysts and designers
- A uniform representation from analysis to design to programming

**Object oriented analysis and object oriented design (OOA/OOD)**

The main aim of Object Oriented Analysis and Design (OOA/OOD) Coad and Yourdan (1991) is a reduction in the complexity of a problem and the system's responsibilities within it. The OOA/OOD method is based on a number of general principles for managing complexity. In the OOA method objects communicate by sending messages. The sender object "sends" a message, that is "received" by the receiver object that takes some action and returns a result to the sender object. The result of applying OOA/OOD results in one main OOA diagram consisting of five layers.

Coad and Yourdan (op cit.) identify seven key reasons for using OOA/OOD, these are:

- The ability to tackle more challenging problem domains
- Improvements in communication between analysts and problem domain experts
- An increase in internal consistency across analysis, design and programming
- An explicit representation of the commonality between classes and objects
- Specifications are more resilient to change
- The results of OOA, OOD and OOP are re-usable
- They provide a consistent underlying representation for analysis, design and programming

**Designing Object Oriented Software (DOOS)**

DOOS (Wirfs-Brock et al, 1990) is divided into an initial exploratory task (Analysis in the software lifecycle) and a detailed analysis task (first part of Design in the software cycle). The main topic of the initial exploratory task is determining the
objects, responsibilities and collaborations of objects that play a role in the real world. In the detailed analysis task the results from the first part are refined and streamlined and a full specification is produced.

DOOS does not distinguish between different types of operations. In the DOOS method communication between Objects is carried out by sending messages. One object sends a message to another object, the receiver, which performs the requested operation and (may) return some information.

The DOOS method is an iterative design method and does not provide rigid guidelines for use. The method suggests that the system design can be validated during development by 'Walk-throughs'. A 'Walk-through' is the use of a selection of valid and invalid execution paths taken from the real world and used by the analyst/designer to see if the design meets its requirements.

Object Modelling Technique (OMT)

The focus of the Object Modelling Technique (OMT) (Rumbaugh et al, 1991) is the identification and organisation of application-domain concepts, instead of implementation domain concepts. As a method it is very rich in notations, and it is claimed that few systems will require the use of all of them.

The Analysis and Design tasks are divided into three parts:

- Analysis: Build a model of the real-world situation starting with a problem statement.
- System Design: Design the overall architecture of the system.
- Object Design: Redefine object structure including details of the system and its implementation.

The OMT approach employs the concept of views. The emerging system is described from three different viewpoints: an Object view, a Dynamic view and a Functional view.

- The Object model describes the object to which something happens (the information flow). It is also used to describe the static structure of objects in a system and their relationships. The object model consists of objects.
- The Functional model describes what happens to an object (the process computations) i.e. the computations within a system. Data Flow Diagrams are used in this process.

- The Dynamic model describes when something happens to an object (the control flow). The dynamic part of every class is described in State Diagrams after initial modelling with Event Flow Diagrams.

The OMT method covers the Analysis task of system development as well as Design and Implementation, it is described as an iterative development method.

**Object oriented Analysis and Design with Applications (OOADA)**

This method was developed by Booch (1994). The OOADA method proposes four models of object oriented development: a logical and physical structure and its static and dynamic semantics. The method emphasises good classification of classes and objects which Booch believes to be fundamental to successful complex system design. It is an evolutionary design method, called 'Round-Trip Gestalt Design': incrementally and iteratively refining the logical and physical views of the system as a whole.

OOADA is divided into a micro and a macro process. The micro process basically represents the daily activities of the developer(s) and consists of four major steps which do not have to be carried out sequentially:

- Identifying classes and objects at a certain level of abstraction.
- Identifying the semantics of the objects and classes.
- Identifying the relationships among classes and objects.
- Implementation of the classes and objects.

The macro process is used for controlling the micro process. It addresses activities for the whole development team on the scale of months or weeks at a time. There are five activities within this process:

- Conceptualisation, in which the core requirements are established.
- Analysis, in which a model of the desired behaviour is developed.
- Design, in which an architecture is created.
Chapter 2

- Evolution, in which the implementation is evolved.
- Maintenance, in which post delivery evolution is managed.

This method addresses Design and Implementation issues including the visibility of objects to each other and the synchronisation of communication between objects.

**Unified Modelling Language (UML)**

UML or Unified Modelling Language, largely developed and marketed by Rational Software™, is an emerging design notation. It sells itself as 'a general-purpose, unified, graphical modelling language for object oriented development' with an emphasis on tasks of object analysis and design. UML is not a new idea, rather a conjunction of existing ideas from Booch, OMT, OOSE and other object oriented methods. As Rational website explains:

'The ideas in the UML come from the community of ideas developed by many different people in the object oriented field. The UML developers did not invent most of these ideas; rather their role was to select and integrate the best idea from OO and other computer-science practices.' (Rational, 1999)

UML is very new. It was first released as the "Unified Method" in 1995. In 1996 a number of large and influential companies (e.g. Digital, HP, Microsoft, IBM, Oracle & Unisys) were encouraged to join forces with Rational Software to expand the original method and more joined in 1997. Version 1.1 of the method was submitted to the Object Management Group (industry standard body) late in 1997 and has now been adopted as a standard (Fowler, 1997).

The goals of the UML development team were to:

- Provide users with a ready to use, expressive visual modelling language so that they can develop and exchange meaningful models.
- Provide extensibility and specialisation mechanisms to extend the core concepts.
- Be independent of particular programming languages and development processes.
- Provide a formal basis for understanding the modelling language.
- Encourage the growth of the OO tools market.
• Support higher level development concepts such as collaborations, frameworks, patterns, and components.

• Integrate best practice.

In addition to Objects and Classes UML employs the concepts of ‘actors’ and ‘use cases’. Actors ‘are everything that needs to exchange information with the system’(Jacobsen et al., 1992) including people, and are not described in detail. Use cases are ‘a behaviourally related sequence of transactions in a dialogue with the system’ (op cit.) and they describe a general description of what happens when a user performs a particular task with the system. UML employs several diagramming methods called ‘Class Diagrams’, ‘Sequence Diagrams’ and ‘Collaboration Diagrams’.

Some parts of the notation are specific to a particular task within the development process e.g. Collaboration Diagrams are used during the design task others are used and expanded on in many parts of the process e.g. Class Diagrams.

The notion of ‘models’ is important to the UML approach. An ‘Analysis’ model is developed quite early and describes the ‘problem space’ : it contains essential Use Case diagrams, a Conceptual model and a Requirements Specification. The ‘Design’ model relates to the solution and contains real Use Cases, Design Class diagrams and Interaction Diagrams.

2.3.6 Discussion of approaches

Hard systems design approaches were introduced to counter increasing costs and levels of failure in software development (Curtis, 1989. Ch13). There can be little doubt that they provided much needed structure and discipline to a software development process which had previously been seen as something of an ‘art’ and which was becomingly increasingly complex. However, once the methods were widely used it became apparent that there were some serious flaws in the ‘hard’ approach. Some of the major problems are said to be that:

• hard approaches assume that an engineering perspective is applicable in all cases. This is clearly not always true. It is particularly inaccurate when the problem to be
solved is unstructured or where there is no common agreement about the potential solution or where the context of the problem is non-stationary. (Curtis, 1989)

- they tend to be mathematically/logically-based which limits their usefulness as not all problems can be solved by maths (op cit.)

- computer software rarely operates in isolation of human users and human users normally operate within the context of an organisation. Hard systems do not adequately address the way in which the human components of the work system are organised (Dobson et al., 1994). They focus on the technical issues at the expense of the social issues.

- the actual reuse of code is limited and is therefore wasteful of effort (Parsons, 1997).

Soft system and object oriented methodologies emerged as a response to these problems but themselves suffer from apparent deficiencies.

Object oriented methods, while different in their approach to standard methods are also very 'hard', in that they focus almost exclusively on the technical aspects of the emerging system. None of the OO methods reviewed for this thesis include constructs or methods by which the human or organisational issues can be adequately modelled. However attempts to amend this are being made (Atrim et al, 1998). UML does model the users interaction with the system within 'use cases' but apparently only at a technical level.

While the 'soft' methods attempt to redress the balance between the social and the technical aspects of system design, and to move away from mathematical and structured approaches, most do so by suggesting themselves as additions to existing hard methods. Some of the methods do not fit in with lifecycle models (i.e. SSM); and those that do are more applicable to the early stages of design than the whole process. The latter point can be made about some of the hard methods as well, see Figure 2.11. Few methods appear to offer support for all development tasks. Multiview was specifically designed to embed socio-technical and soft systems into a broader methodology but it fails to address feasibility and validation tasks. The only method which appears to specifically encompass the whole design process is DSDM.
Another criticism of ‘soft’ methods is that they do not provide ready to use tools to integrate their results with those from the technical evaluation. Although ORDIT comes with a toolkit for identifying and specifying requirements it does not provide the means to link these directly into the documentation process of any existing hard methods. It is entirely possible with many soft methods for an extensive user and organisational survey to be completed and for the results to remain within a report instead of being integrated into the design. In one large European project (Siemieniuch, 1990), despite full user participation in the requirements task and extensive documentation, constant reminders of the contents of the specification were needed to keep designers on-track. The need to formalise this translation process is recognised (Jirotka, 1994) although there are arguments against over-formalisation (Truex & Klein, 1991; McDermid, 1994) which can be seen as trapping the project into an early and potentially incomplete specification.

‘Soft’ methods have often been viewed with suspicion by developers, as most are not ‘stand-alone’ and they cannot demonstrate the same track records as established ‘hard’
methodologies. The Star method for example is known largely through HCI publications such as the textbook by Preece et al. (1994).

It has been argued by a number of authors (e.g. Baroudi et al., 1986; Karat, 1990; Mantei & Teorey, 1988), in addition to those mentioned at the start of the ‘soft’ methodologies section, that a user-centred or participatory approach has direct and observable benefits in terms of costs and time. Despite this, user-centred design principles are still rarely practised in commercial software development (Rossen et al., 1987). It has been suggested that this is due, in part, to a lack of any clear and empirical evidence that user participation actually provides benefits within a commercial software environment. Ives and Olson (Ives & Olson, 1984) suggest that extensive user involvement may lengthen the implementation period, alienate those who cannot be involved, force design compromise and build up opposition to implementation. Software managers may also resent the loss of control that ‘soft’ and ‘user-centred’ methods imply.

These findings were supported in a more recent study by Heinbokel et al (Heinbokel et al., 1996). In a longitudinal investigation of 29 commercial software development projects, the pros and cons for user-centredness in software development were analysed. It was found that user involvement was negatively correlated to innovations within a software development team, team flexibility and team effectiveness. User orientation within the design process was positively correlated to degree of stress in the development teams working situation, and negatively correlated to team effectiveness and quality of team interaction. The authors concluded that previous naive statements suggesting that user-centred design is all positive need to be modified. They proposed that user-centred design was still the best choice for users but that account needed to be taken of the fact that it was an uncomfortable and difficult choice for developers.

Summarising these studies, it appears that involving users in the design process is a useful thing to do. Handled sensitively, user involvement can inform design and win support. The design method however has to be aware of the limitations placed on the developer and the restrictions under which they operate. Whether developers are working from an object oriented perspective, or schooled with SSADM, integrating end user and
organisational issues into the design methodology can only occur if it fits into existing ways of working: the identical argument used to justify the use of soft systems in the first place. Only by an understanding of the ways in which systems designers operate, the limitations placed on them by the production environment, can soft concepts be integrated successfully. Within the context of this thesis the limitations placed on the designers of crop production DSS and the implications for a design methodology are discussed in detail in Chapter 5.

The ideal software design methodology should contain aspects of both hard and soft approaches, involving users but keeping the development process needs in view. The only method discussed above which approaches this ideal is DSDM. It alone seems to contain the best parts of both approaches i.e. the structure and formalism of the hard approach and the wide perspective of the soft approach. Although it is a technique specifically designed for Rapid Application Development and therefore quite narrowly focused, the majority of its underlying principles can be usefully applied within most projects.

This discussion concludes that of all the methods described above the only one to merge social and technical considerations and to offer support for the complete design process is DSDM. While its detail is only applicable to RAD it provides a useful set of principles on which to base any design method, incorporating the fundamentals of user-centredness, involvement and iteration.

2.4 TOOLS AND TECHNIQUES

The adoption of any user-centred design method requires the use of tools and techniques to facilitate the gathering of requirements from users, their incorporation into the design task, and the subsequent evaluation of the emerging system. This section describes the main techniques used in the design process for the projects described in Chapter 3.

In the studies described in this thesis the focus of effort (as in most human factors tasks in design) is in the requirements and evaluation tasks and these can be, and are, frequently viewed as distinct activities. If, however, design is seen from the evolutionary
perspective then these tasks merge and overlap until they are practically indistinguishable from one another. For example using a prototype with users can be seen as an evaluation tool but it is equally likely to generate new requirements, as users see new, or different ways in which they can use a technology they could not previously visualise.

The main tools available to the human factors specialist engaged in iterative requirements analysis are described in the RESPECT (Maguire, 1997) handbook as:

- Brainstorm
- Controlled testing
- Diary keeping
- Focus group
- Functionality matrix
- Group discussion
- Interviews
- Observation
- Paper prototyping
- Parallel design
- Rapid prototyping
- Scenario building
- Storyboarding
- Survey
- Task analysis
- Task allocation
- Video prototyping
- Walkthrough
- Wizard of Oz prototyping

These are described briefly below:

**2.4.1 Brainstorming**

A method used to generate ideas, usually in the early stages of design, but it can also be useful for solving specific design problems at any point. In this method a group of
experts are brought together to ‘bounce’ ideas off each other. The format of a brainstorming session is very informal and all ideas are taken seriously and thought through creatively. The aim of these sessions in the design process is to get a feel for the scope of a design solution and some specific design ideas.

2.4.2 Controlled testing

This method is usually used in the evaluation phase of new design but can also be adopted as a means of identifying problems with existing systems to inform the requirement phase of a new project. In this method representative users are asked to perform tasks in a controlled environment e.g. a laboratory and their performance is logged and/or recorded for later analysis.

2.4.3 Diary keeping

A method in which a view of the user’s activities is gained by analysis of diaries recorded by the user on a daily basis. These diaries can vary in the degree of structure they impose on the user, from very tightly structured, with extensive use of tick boxes and multiple choice options, to completely free form. Normally pen and paper are used for these diaries but more recently available techniques include on-line reporting and video diaries.

2.4.4 Focus groups/workshops/group discussions

These are similar in that groups of stakeholders are brought together to discuss issues relevant to the project in hand. These groups can be used to discuss existing problems and needs, new ideas, design options, costs and benefits, screen layouts, etc. Bringing individuals together can stimulate and free them to provide more information for the requirements gathering process. By a process of discussion it is also hoped that a collective view will become established.

2.4.5 Functionality matrix

A method developed as part of the HUFIT toolkit (Catterall, 1990). The aim is to identify the system functions that each user will require for the various tasks that the user will perform. The matrix can be used to check the extent to which the system meets these requirements. Critical tasks are separated from occasional tasks so that more effort
can be spent on evaluating them. This method is intended to be used as both a requirements gathering tool and a means of evaluating the system during development.

2.4.6 Interview

In this technique potential users are asked questions by an interviewer in order to gain knowledge about the users tasks, problems, requirements etc. Like diaries, interviews can vary in the level of structure they impose. Some are completely structured i.e. based rigidly on a set of questions, others are completely unstructured, where the interviewee places no boundaries on the material covered by the interviewee. The most common type of interview however is called semi-structured, where answers to specific questions are sought but where the interviewee is free to cover other areas as well. The RESPECT handbook (Maguire, 1997. pp.106) suggests that structured interviewing should only be carried out in situations where the respondent’s range of replies is already well known and there is a need to gauge the strength of each shade of opinion. Semi-structured interviews, are said to be useful in situations where broad issues may be understood but where the range of respondent’s reactions to these issues either is not known or is suspected to be incomplete.

2.4.7 Observation

In this technique the stakeholders are observed while they work and notes are taken by the investigating agent. The observation can be overt i.e. the investigator is actually present in the same room/space as the observed, or covert, where the investigator is observing without being in the same physical space as the observed. In the latter case the observer may be on the other side of a one way mirror or viewing via video. Ethical considerations are especially important here.

2.4.8 Survey

See 2.4.13.
2.4.9 Rapid Prototyping/paper prototyping/video prototyping/Wizard of Oz prototyping

These items have been grouped together because, unlike the RESPECT handbook, this author views them as aspects of the same process. The use of prototypes is one of the cornerstones of participative design. Prototyping provides a mechanism by which users can be involved in the design process. The aim of prototyping, whether on paper or on the screen is to get feedback at an early stage on the design and function of the emerging system. Paper drawings of the system may be used in the earliest of stages because it is the easiest and cheapest way to take ideas to the user. Rapid prototyping tools such as Visual Basic™ or Macromind Director™ are used for the same purpose but require a little more time to produce. Video prototyping is an advanced form of paper prototyping where the dynamics of the system are animated using paper sketches and static objects such as pens to mimic cursor movement etc. Wizard of Oz prototyping is used when it is not possible to provide a realistic prototype using a computer but where feedback on the concept is still required e.g. mocking up response to novel input devices such as speech input or eye-blink control, the user may think the system is controlling the device but it is controlled manually by an unseen experimenter.

Displaying ideas on screen will generate more detailed response than paper and so this may be considered more cost effective to use when the main design ideas have been agreed. Conversely as a more accurate picture of the design idea is conveyed by system-based prototyping, and as the tools are increasingly easy to use, it may in some cases be more cost effective to use it instead of paper-based feedback. Where computer-based prototyping is costly and paper ineffective, a Wizard of OZ or Video prototype may be considered.

2.4.10 Parallel design

A process by which different designers working independently generate different design solutions. The idea is then that these ideas are combined and the best parts of each incorporated into the final design. This is a design method rather than a requirements or evaluation tool but its results can be used within the requirements process.
2.4.11 Scenario building

A scenario is a story which describes the typical users of a system and the ways in which they interact with it to carry out a task. A scenario may describe the situation as it currently exists or as it may exist when a new system is implemented. A scenario can be used in a number of ways. As a description of existing conditions it can be used as a means of clarifying understanding with users i.e. did the interviewers translate the interview correctly. As a description of a future scene it can be used as both a requirements generation and evaluation tool. In this aspect it operates as a dynamic form of the prototype, describing the effect of the new system on the activities and interactions of the users.

2.4.12 Storyboarding

Sequences of images which demonstrate the relationship between individual events. Storyboards can be seen as components of prototyping. The linking of images is used to explain the relationship between screens and system structures and the type of navigation that will be possible within the system. As a prototyping tool this method can be used both to evaluate system ideas and to generate new requirements.

2.4.13 Survey or Postal survey

A survey is a means of asking a large sample of people a set of standard questions. The survey may be conducted face-to-face (as in street surveys) or through the post. As with all question-based approaches, respondents can be forced to choose from a set of answers or left free to answer in their own words. Surveys are usually employed in the requirements analysis task either as a means of identifying current practices or preferences or for checking the validity of current understanding of the same.

2.4.14 Task analysis

Task analysis has been defined as ‘the study of what an operator (or team of operators) is required to do, in terms of actions and/or cognitive processes, to achieve a system goal.’ (Kirwan & Ainsworth, 1993, p1). Task analysis is usually conducted to identify the main components of the current task and the information flows within it. It is a methodology,
supported by a number of techniques to support the analyst in collecting information, organising it and using it as the basis for design decisions. The aim of task analysis is to draw up a 'blueprint', or detailed picture of the system from a human perspective. The blueprint is then used to ensure that tasks and functions are appropriately allocated within the new system.

2.4.15 Task Allocation
An approach used to decide on the best allocation of functions between the user and the system. This method can be used in the requirements identification task.

2.4.16 Walkthrough
This term can have two meanings. In one it is a means of walking the user through a system design, which can be manifested in a prototype or in a complete system. In the second it is a way of the user showing an observer the normal use of a system by walking them through a typical interaction. In both cases it can be used to elicit requirements or to evaluate the performance and usability of a system.

2.4.17 Workshop/Focus groups
A workshop is defined as a 'meeting of several persons for intensive discussion' (Sykes, 1983). In the system development process the discussion is normally concerned with some aspect of software design. A workshop usually consists of between three and eight. The workshop may be used early in system design to identify problems that need solving, key tasks and restrictions; or during the design task to evaluate and comment on design solutions. Brainstorming may be used within the early task phases. Workshops can be used after release to gather and focus opinion on aspects of system function and usability. A focus group is the name sometimes given to a product-based workshop.

2.5 THE METHODS ADOPTED WITHIN THIS THESIS
The studies described in the next chapter were carried out within the confines of a number of different projects and this has a bearing on the models and methods used within them.
A user-centred approach was employed for the reasons given in the section above, and the iterative model, which is central to the participative approach, was adopted as far as project limitations allowed. The degree of iteration was frequently less than ideal in reality because:

- Work was funded for a limited duration
  
  Unlike commercial software development, research project budgets tend to run for one, two or three year periods and their primary aim is rarely the production of robust code. Two of the projects described in Chapter three were of one year duration. The degree of iteration possible in such a time period is obviously limited.

- The agricultural and horticultural working year produce short ‘windows’ in which users are willing to become involved in research and development work.

  Coupled with the short duration of the project, access to users in the agricultural sectors is quite often restricted to ‘quiet’ periods of the year. Stock enterprises don’t have quiet period as such but crop producers are more willing to participate in non-farm activities between November and the end of February. Some of the Spring and Summer months are particularly busy and users simply cannot allocate time to such secondary non-farm tasks.

- The pace of development is frequently dictated by technical partners, i.e. those involved in writing the code and developing the mathematical models.

  Although every effort is made to synchronise the user and technical activities within the context of a research project sometimes the limitations on time outlined above are restricted further by the practical problems associated with code production, e.g.:

  - The space between user ‘windows’ may not be long enough to complete coding or specification of the models
  
  - The production of code or model may not go according to plan – quite common with DSS as both models and systems are still ‘leading edge’ and hard to predict.
As user activities such as evaluation are dependent on delivery of software and software design & development can be dependent on feedback from users these restrictions can severely restrict the number of iterations a project can perform.

Although a large number of methods exist and have been described briefly above, no specific method was adopted for the projects discussed in the next chapter, although the principles of DSDM (as outlined above) were adopted as far as was practicable. These principles are also incorporated as far as possible in the methodology outlined in Chapter 5 where the specific problems and requirements relating to the development of an agricultural DSS method are discussed. In general, the problems that existing methods create for the Agricultural DSS developer are as follows:

- Hard methods are not sufficiently user-centred
- Most soft methods are not sufficiently tied into the design process to be useful
- With the exception of DSDM all methods are designed for large scale software developments
- DSDM is designed for small scale projects within an organisation
- None of the available methods are specific to DSS or information systems

Due to the nature of the projects within which the research was conducted and the research specialism of the author, the focus of attention in all cases has been on the requirements analysis and evaluation tasks, with some input to design. The main tools and techniques employed within the studies, to generate and validate user requirements, design and evaluate the emerging system, within a user-centred paradigm, are shown in Table 2.2:

<table>
<thead>
<tr>
<th>Table 2.2: Use of tools and techniques for specific product development tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility/initial requirements</td>
</tr>
<tr>
<td>Workshops</td>
</tr>
<tr>
<td>Brainstorming Prototyping</td>
</tr>
<tr>
<td>Interviews Brainstorming Interviews</td>
</tr>
</tbody>
</table>
Face-to-face interviews are a costly but useful means of generating detail at the start of a project, they can be used to scope the problem and to get a deep understanding of facets of the user's task and working environment. Workshops, as illustrated in DSDM, are a cost effective and useful way to get user input at all points in the product lifecycle. Postal surveys cannot provide detailed information but are very useful for checking the validity of assumptions with a large number of geographically dispersed users. Prototyping is used for requirements generation, validation and design validation, initially with paper mock-ups and later with screen-based mock-ups. It has been found to be the most useful way to feed requirements back to users and to give a 'feel' for the emerging software to generate new or more detailed responses. Brainstorming is a very cost effective means of scoping the project initially and generating design ideas. It can also be used in user workshops for generating requirements. Where only partial functionality (or mock functionality) can be obtained in a prototype the use of a typical 'storyboard' or scenario is essential to the transmission of a vision of the system in action. Written scenarios can also be used. Controlled testing is not often an option in small scale projects due to its cost. It can be used to spot major problems and test usability in a product prior to field testing. Field testing, or testing in the work environment called 'beta' testing in mainstream software development is the last stage in the testing process but again is not always possible in small projects.
3.0  PROJECT WORK CONTRIBUTING TO THE THESIS

3.1  AIM OF THE CHAPTER

The conclusions drawn in this thesis are based on experience and data drawn from individual pieces of research carried out within a number of MAFF funded projects over a period of five years. These studies, unlike those described within a conventional thesis, are not a pre-planned series of investigations leading towards a pre-defined goal. However from observations made during the course of these studies and the data generated from within them, it is possible to make statements about the industry as a whole and about the nature of the DSS and software development process within crop production. As suggested in the previous chapter, this degree of understanding is critical to the development of a DSS development method, which meets the needs of users and developers alike.

The function of this chapter is to provide a brief description of each project and project component on which the author has worked and which has contributed in a significant way to the body of the thesis. Conventions are observed in so far as each project description contains an introduction, laying out the aims of the research, a method and a summary of results. Much of the background detail from the original research has however been omitted: its inclusion (to the level expected in a conventional thesis) would probably result in a book resembling the Encyclopaedia Britannica in size and digestibility. Original project reports are included as appendices to provide the necessary supporting documentation.

It is apposite to know the author's role in these projects. The author is employed to carry out research with the Human Sciences and Advanced Technology Institute (HUSAT) at Loughborough University. She was solely responsible for negotiating HUSAT's contribution within the collaborative research outlined below. While some aspects of data gathering were shared with other HUSAT employees (these are clearly indicated in the script), all of the analyses and conclusions were the work of the author alone.
3.2 SCOPE OF THE CHAPTER

The research described below relates to four projects and components within them. These projects and their timescales are listed below:

HORticultural Information System (HORIS) 1996-1997
Technology transfer in Modelling (TIM) 1996-1997

Although very different in size and focus, each project relates to a different aspect of the technology transfer process and has made it possible to gain a broad perspective on the problems relating to technology transfer in crop production. GRIME, HORIS and TIM were based in the horticulture sector and focused largely on brassica and top fruit crops; DESSAC is based in the arable sector and is focused largely on winter wheat.

Each project relates to a different point in the technology transfer process and therefore provides a useful insight into the requirements from each of these perspectives.

Figure 3.1 illustrates the ways in which they interlink. GRIME is concerned with the development of models and with providing a means to deliver them to the industry within decision support systems. The GRIME system supports the research institute in model development by providing a model development tool. The output of the modelling exercise can either be delivered back to the institute through the ‘science interface’, for further development or incorporation into larger models, or through a variety of grower/consultant interfaces. DESSAC is concerned with providing an integrated delivery mechanism for decision support tools, and with demonstrating its viability with a DSS called the Wheat Disease Module (WDM). TIM is concerned with finding ways to educate the industry about model-based decision support and with a means of feeding the
industries requirements back to the scientist. GRIME, DESSAC and TIM are all concerned with DSS as technology transfer mechanisms, HORIS on the other hand is an information system, concerned with the issues surrounding the provision of encyclopaedic information to the industry.

![Figure 3.1: Illustrating links between projects contributing to this thesis](image)

The projects are described in the following sections. GRIME and DESSAC are complex projects and are divided into smaller units, each describing a specific and functionally distinct piece of work. In all cases the aim of the work, the author's specific role within it, the methods employed and a summary of results, are provided.
3.3 GRIME RESEARCH

3.3.1 General introduction to GRIME research.

The work carried out under the GRIME project heading has been in progress since 1993 and is due to be completed in 2000. The data of interest to this project however was generated in the early part of the project, during the period 1993-1997. The overall objective of this three year MAFF-commission funded work was to design a system for interlinking and transferring models from research to commercial horticulture. The partners in the project were Horticultural Research International, Computer Studies at Loughborough University and HUSAT. The project was divided into four separate but inter-related areas of research.

1 Identification of requirements from potential users.
2 Design of a flexible structure for integrating models.
3 Investigation of the acquisition of meteorological data.
4 Development and testing of a prototype, proof of concept, and demonstrator of novel software for use by both research scientists and the horticultural industry.

The author’s role in the project was to manage and effect the first of these objectives, the identification of user requirements and to provide input to the fourth. Users in this instance were both industry-based (i.e. growers and consultants) and science-based (i.e. the biologists who create models).

Two aspects of the first objective are described in the studies below. The first is concerned with a user requirements survey, the full report of which can be found in Appendix A and was also described in Parker & Phelps (1994). The second aspect comprised a study of the DSS user interface requirements for growers and consultants in this sector. This provides the background to the later DESSAC interface work and to the
interface guidelines proposed in Chapter 6. The official report of the interface-based research is presented in Appendix B.

3.3.2 Requirements surveys

Aim of the research

The aim of the requirements surveys in GRIME was to identify the user requirements of two of the target user populations, brassica growers and advisors/consultants to the brassica growers. This activity was seen as central to the 'user-centred design' approach adopted by the project (see Chapter 2); the first aim of user-centred design being to ensure that the user's needs serve as the focus of the design process.

Preece (1993) suggests that a project which aims to deliver any form of software technology should first answer some basic questions. In the context of the GRIME project these translate as:

- Does the industry need DSS technology?
- Is the underpinning technology available and is it logistically feasible?
- What will they use it for (what are the key areas)?
- Who will use it?
- What is the work context and environment in which it will be used?

These questions can be further specified as:

A is there a need for prediction/forecasting models in the grower/advisor population, or are the existing sources of information adequate?

- Do all growers and advisors have a requirement for such systems?
- If there is a requirement, how widespread is it?
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B Do the technological and informational components required for prediction/forecasting models exist, and if not, is it likely that these will become available in the near future?

- Do growers/advisors have access to suitable computer systems and to the meteorological data utilised by forecasting models?
- If not, would they be willing to gain access given suitable incentives?

C Where will prediction/forecasting models be of most use?

- Which particular pests, diseases and nutritional requirements do growers/advisors consider to be most important?

D Within what constraints do the users operate?

- What are the goals of the users and their companies?
- What are their markets and what pressures do these exert?
- Are there any other relevant external influences?
- What changes (technical, economic, political) are currently taking place or likely to take place in the near future which might impact the use of DSS or computers?

E What type of interface requirements should be taken into consideration when building the system?

- Who are the potential users?
- Do they have computer skills?
- What other tasks will they be carrying out?
- What other facilities might be built in to ensure that the system is used?
The aim of the requirements survey was to provide answers to these questions and therefore provide an appropriate starting point for the development of the GRIME system and any associated DSS.

The full report of the user requirements survey for GRIME can be found in Appendix A.

The role of the author

The author’s role in this research was to identify and define the methods required to adopt a user-centred approach and to manage and carry out the research, i.e.:

- Define questions
- Develop questionnaires and other methods for gathering data
- Identify stakeholders
- Organise and conduct interviews/postal survey
- Analyse and present results

Method

The first three questions

- Does the industry need DSS technology?
- Is the underpinning technology available and is it logistically feasible?
- What will they use it for (what are the key areas)?

are fairly straightforward and can be answered, to an extent, by simple yes/no responses. As such they were capable of being incorporated into a postal questionnaire. As outlined in Sections 2.4.13 and 2.5, postal surveys have the advantage of being cheap and capable of eliciting responses from a larger group of people than would otherwise be possible. This type of survey however lacks the richness of data associated with interview techniques and so the same questions were also asked of a sample of growers and advisors during face-to-face interviews to add greater detail to the survey results and to provide useful case studies.
The final two questions, concerning the characteristics of the users, their tasks and the constraints under which they operate, are more complex and not easily posed in a paper format. Knowledge about these issues was obtained both from background reading and from structured interviews with a sample of the user population.

Three preliminary interviews were carried out in December 1993 with the aim of clarifying the problem area, i.e. identifying areas of interest, useful questions for use in later interviews and the tasks and roles of those involved in the growing process. While these interviews were largely unstructured, a number of prepared questions were pursued. The questions formulated from this process were then divided according to their suitability for a postal questionnaire or face-to-face interview. Both types of data were brought together in analysis, i.e., the postal questionnaire data provided the profile of computers in use and the interview data gave clues as to why this profile existed.

Fifteen face-to-face semi-structured interviews were finally conducted. The sample comprised four consultants and 11 growers, sampled from across the key brassica growing districts and from a range of company sizes. Four of the interviewees were advisors (two ADAS\textsuperscript{10}, two independent), and the rest were growers. Time was also spent talking to a couple of the people 'who do the typing in' at the smaller growers, usually wives.

The postal questionnaire was distributed to approximately 250 horticulturists, who were contacted through a number of sources, the largest being a mailing list from the Horticultural Development Council, the levy body for the sector.

**Summary of results**

Approximately 200 questionnaires were distributed to brassica growers and 50 to vegetable consultants. A total of 78 growers and 18 consultants replied (36-40\% return rate) and most of the key growing areas were represented. The results can be summarised under the following headings:
• Support for development of model-based systems

The results strongly suggested that the sector wanted the type of information that prediction/forecasting models could provide. These systems were of most interest to advisors and consultants and to co-operative organisations rather than to the smaller enterprise. Models describing the behaviour of pests, diseases and nutrition were all seen as important and within these categories certain problems were given particular emphasis. The need for a system to gather and integrate farm data into models was also identified, making them more local and reliable and reducing the need for data re-entry.

• Adequate computer base to support development

The research revealed that, contrary to expectation and previous research (e.g. Palmer, 1992) there was a reasonably large computer base for the technology. The survey data showed that 60% of respondents owned a computer and that the number was growing.

• Limited access to meteorological data

The survey revealed limited local capability to provide the more complex type of often used in crop modelling. It was therefore concluded that models which rely on rainfall, min/max temperature and wind-speed, and are not too particular about the distance from the source of the data, would be most successful.

Some of the most interesting findings from the research related to the constraints under which growers operate, e.g.:

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- Market constraints: The bulk of the vegetable producing business in the UK is controlled by approximately 20 individuals, all of whom seek contracts from the five main supermarket buyers. Multiple retailers have an enormous power within the industry and the needs of the grower in relation to their buyers is critical.

- Information constraints: The research highlighted the problems created by the separation of near market and basic research. This separation limited access to particular types of research and reduced the ability adequately to test systems in the field prior to commercial development.

- Time constraints: Time was found to be one of the most important constraints on the grower and the grower's acceptance of model-based systems. These users made it very clear that they would reject systems which required them to spend more time at the computer than the actual procedure the computer was intended to replace - unless the computer system offered substantial benefits. The need to pay close attention to the utility and usability of DSS systems was emphasised by this finding.

The full set of results can be found in Appendix A.

3.3.3 Survey of interface requirements

Aim of the research

One of the intentions of the GRIME research was to identify, design and test a set of generic interface features for horticultural DSS. In the process of analysing the types of questions the potential users said they wanted to ask of a DSS, it became apparent that there was a considerable degree of overlap between seemingly distinct topic areas. For example growers and consultants were interested in risk and timing questions whether or not the topic in question was pest, disease, weed or irrigation. If this was indeed the case then, it was suggested, the technology transfer process could be facilitated by the development of a few 'bolt together' interface components. Model code from GRIME could be slipped directly into a basic generic interface with additional interface features added as appropriate. It was suggested that this approach would considerably reduce the
delivery time for an agricultural DSS, dramatically increase consistency and have the added benefit of proven user acceptability. In the event the focus of the project left this task unfinished but its findings were incorporated into the DESSAC interface design which is described in Chapter 6.

The aim of the research activity described below was to start the process of generating a set of generic design components and testing them with users. The departure point for this design process was the results from the survey described in the previous section. These results suggested that the interface to any model-based system had to provide several things in order to be successful, it had to:

- Present the user with the information they needed immediately - growers spoke of having ten minutes in the office between jobs and of needing to check disease/pest status within that time.

- Present the user with all the main features of the information they need and with simple methods of changing parameters. Those interviewed were very impatient with systems that insisted they go through layers of menus to change key parameters. Direct manipulation of information seemed to be essential. Time is always of the essence.

- Present users with the output of several related biological models at the same time. Being able to see the status of several pests and diseases or of other areas of interest is important to the user when making decisions and prioritising information.

- Allow users to see the results of changing variables and compare the results of several changes on the same screen. In order to make a decision between two or more possible solutions or potential outcomes the user needs to be able to see the results of their manipulations on the screen at the same time.

This information and the specific questions the users said they wanted to ask of the system (see Section 6.1.5) were used as the basis for the design. The full report of the user interface requirements research can be found in Appendix B.
The role of the author

The author's role in this research was to identify and define the way in which the generic interface components could facilitate the technology transfer process; to develop the initial design and to test it with a sample of users i.e.

- Define problem and solution and link with other GRIME components
- Develop initial designs
- Formulate and develop method of testing design with users
- Organise and conduct evaluation
- Analyse and present results

Method

There were two stages in the development of the interface design in GRIME. The first stage began before the results of the user survey were fully analysed. Its primary aim was to test the ability of the core GRIME software (called HIPPO) to generate code and to identify generic problems i.e. how to integrate with the model such that an appropriate level of information might be displayed to different levels of user (grower, consultant, biologist).

After a period of time it became apparent that the use of Visual Basic was hampering the user interface design process. The degree of coding required to make small changes at the interface and the impact of those changes on the underlying links to the HIPPO software made the process of change unacceptably slow. The task of generating acceptable interface features was separated from that of testing the technical aspects of linking with the HIPPO software. The second stage of interface design focused entirely on the presentation of information at the interface.

An animation and presentation package called Macromind Director™ was employed during this stage (see Section 2.4 for a discussion of the use of rapid prototyping tools) as a direct result of its successful use in an unrelated project with the automotive industry (Cooper, 1994). This software was used to rapidly design and animate a sequence of
potential actions for demonstration. The actions were in turn based on task ‘scenarios’ (see Section 2.4) originally described by growers and consultants during the interviews discussed in the previous section. Unlike the Visual Basic approach there was no real ‘code’ or functionality associated with the design, it therefore took a small fraction of the time to produce and was very easy to adapt in response to user comments.

Applying the requirements described earlier (i.e. immediate access to key information; easy means of manipulating and changing model parameters; immediate visibility of results of changes; combined view of the output of several related models) resulted in the design shown in Figure 3.2.

The main area of the screen [A] is used to display the output of any number of models. The choice of models to display is given by the dialog area labelled [B] in the figure. The areas labelled [C] allow the user to change the inputs to the models and to the display of meteorological data on the screen. A ‘run’ model button was employed to allow the user to make a variety of changes to the scenario before manually re-running the model: the time taken for each run being deemed too long for automatic activation to be acceptable.

The screen design also allowed the user to manipulate directly the weather and spray date information in the main screen area. In a design approach based on the German ProPlant system (Visser et al., 1994) the design suggested that users could ‘pick up’ the edges of the graphical features (histogram bars and graph points) and move them to new positions, the movement of position being indicated by a pop-up display. To complement this feature users were also to be given the ability to ‘slide’ the spray application date (small red triangle on the date line at the bottom of the main display area) to a new position and see the impact of the change on the variables of choice. It was felt that this design would meet the requirements outlined above and be generic enough to meet the display needs of the majority of time-based simulation models. Non-time-based models would require a slightly different approach. A full description and justification of the interface design can be found in the document in Appendix B.
Six farmers and one adviser were involved in the evaluation of the interface design in a walkthrough-based interview which lasted between sixty and ninety minutes. The concepts behind the design were explained and each user was informed that the system was a demonstration tool and in a fairly early stage of development. Users were asked to point out interface features, wording and dialogue structure which caused them problems (e.g. didn't make sense or irritated them).

During the 'walkthrough' the interviewer talked the user through several potential scenarios. At each stage in the dialogue users were asked standard questions about particular features of interest. They were also asked what they thought they were supposed to do at each stage and whether they understood the purpose of the window and the method of interacting with it. All interviews were tape recorded with the permission of the interviewee.
Summary of results

The general approach of the screen layout shown in Figure 3.2 was approved by all interviewees, particularly the speed of access as 'scientists have eight hours a day to play with it and farmers only have five minutes' (user quote from interviews). The graphical display was seen as easy to use and useful by all of the interviewees and the display of meteorological data was also appreciated, as one user pointed out 'it's easy to move and to see'. The ability to pick up and change the data levels and spray dates dynamically was seen as particularly useful. This type of 'what if' manipulation is particularly important for making decisions about risk assessment, workload and tank mixes. On the negative side several users said that they would like to be able to change all of the met values by one or two points at once, enter data directly into table cells, and view more than a field at a time. The ability to run automatically in the background and produce print-out warnings was seen as important.

The design and the main conclusions from this research were used in the subsequent DESSAC project. There were:

- the importance of the interface to the take-up of DSS
- the need to provide all the most important information on the screen
- the need to support 'what if' manipulations, and
- the need to make changes to data easy.

The DESSAC interface design, despite having had the benefit of a large number of design iterations, still adheres to most of these principles and retains a number of the design features first proposed in the GRIME project. These principles are discussed further in Chapter 6.
3.4 DESSAC RESEARCH

3.3.1 General introduction to DESSAC research.

During 1993 and early 1994 discussions between MAFF, HGCA, crop agronomists and researchers, as well as representatives from the agrochemical industry, developed a series of ideas for arable crop decision support systems (DSS). These culminated in the initiation of an ambitious five year MAFF LINK funded project called DESSAC, DEcision Support System for Arable Crops.

The originators of the DESSAC concept realised that decision support systems had a great deal of potential which could be harnessed to solve some of the problems of technology transfer. The prime goal of the DESSAC concept is to provide a suite of integrated computer-based decision support systems (modules) designed to address all of the key decisions facing arable crop farmers.

The two main barriers to the success of these systems were perceived as (a) the lack of integration between DSS and existing farm data which required the user to re-enter data each time they used a new system and (b) the lack of user friendliness of previous systems.

The DESSAC approach to the first problem has been to construct a generic framework or "Shell". This is a software environment in which DSS modules can operate and interact and which contains standard data they commonly need, such as:-

- climate data, recent past and forecast weather.
- farm data such as soil type, sowing dates and fertiliser usage.
- pesticide data
- data on crop varieties

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To facilitate the development of modules which can operate inside this 'shell' a 'toolkit' has also been developed. This toolkit and the DESSAC database descriptions act as a form of Standard to which, it is hoped, future DSS of all types can be developed and to which all major crop management software developers can link their program output.

In contrast to many DSS development projects in this sector the DESSAC project devoted a considerable amount of effort and funding to overcome the second problem outlined above, that of 'user friendliness'. These efforts and funding for an early user requirements survey were largely due to a paper by Berry (1994) and the vision of the project initiators, particularly Robert Cook (then Director of the Morley Research Centre) and the project funding bodies (Ministry of Agriculture, Fisheries and Food and the Home Grown Cereals Authority).

**The role of the author**

HUSAT was involved in the project from the beginning of the funded period. In an initial pre-project phases, the author, as HUSAT representative, participated as a member of a team responsible for user requirements capture. When HUSAT were invited into the full project consortium the role became that of person responsible for developing and implementing the user-centred design strategy within the context of a project 'User Needs Group' headed by Robert Cook. The DESSAC consortium comprises: ADAS, Farmplan (Optimix), HUSAT Research Institute, IACR Rothamstead, Morley Research Centre, and Silsoe Research Institute. The funding bodies are MAFF and the Home Grown Cereals Authority (HGCA).

**3.4.2 User requirements interviews**

**The aim of the research**

The aim of the early requirements interviews was to examine the decision processes relating to arable crops and to determine in which areas decision support systems might be of particular relevance to users. Although the focus of the project was to be fungicide
use for Winter Wheat, the User Needs Group was initially directed to examine the whole decision process and the context in which decisions took place.

The stakeholders for this system were classed, at this stage, as anyone who made use of complex information to aid in the production of arable crops, and three main classes of users were identified, farmers, chemical representatives and independent advisors. The full report of the user requirements exercises can be found in Appendices C and D.

The role of the author

The author worked with the ADAS Ergonomics unit to develop a questionnaire for use in structured interviews. The questions were developed as a team activity but the interviews were divided into two parts. The author interviewed farmers and consultants in the North and Midlands counties and ADAS those in the South. The combined questionnaire and interview data was analysed and presented by the author, working alone.

Method

Interviews were conducted in two phases. The first phase was considered by members of the steering panel to contain too few large farm units and a second phase was therefore introduced which concentrated on this sector. The focus and format of both phases was sufficiently similar to report them here as a single study, although the original reports are included as Appendices C and D.

Interviewees within the target groups were selected at random, within pre-defined geographical locations from: the ADAS database; the Association of Independent Crop Consultants 'Directory of Members' and the Yellow Pages.

The interviews were semi-structured i.e. although a degree of free response was encouraged (to provide the 'depth' as described in the GRIME studies earlier) a questionnaire formed the basis of the interview procedure. All respondents were asked the same questions in the same order to try to ensure a degree of commonality in the reports from the author and ADAS. The procedure was as follows.
Each interviewee was asked to talk their way through the growing year, outlining the decisions that had to be made in relation to a winter wheat crop. During this process, which took up more than half of the 1-1.5 hour interview slot, the interviewer asked questions as to the nature, source and importance of information used to make decisions, the roles of farmer and adviser, and the use of computers. A list of standard 'prompts' were used.

While the questionnaire was designed to extract information on the existing situation and on the information needs as currently perceived by the users, an additional validation tool, the scenario, was employed in the second set of interviews to elicit feedback on futuristic suggestions. A scenario in this context is a story-like description of a proposed system in use in a situation familiar to the users (see Appendix D for an example). Four scenarios were devised and from these three were chosen for use in the interviews; two for farmers and one for advisers. The bias towards large farms in the data resulting from the scenario exercise was not felt to be a problem as it was generally perceived, both within the consortium and among its sponsors, that large farms and consultants would be the primary users of the system. All interviews were recorded with permission.

**Summary of results**

The two surveys together contained data from 44 interviews. These were made up of 32 farmers (cereal acreage covering 14 to 1150 acres) and 12 advisers, comprising two ADAS, four chemical company representatives and six independent advisers, with cereal acreage ranging from 2,500 acres to 14,000 acres.

The main impression created by both surveys was one of consistency; the same requirements appeared again and again. The initial expectation had been to find a range of disparate groups with differing needs but the reality was a continuum of requirements, from low-tech farmer to high-tech adviser, with an overlap of requirements in the middle ground.

Again, contrary to the expectation of the project, there was little evidence of technophobia in either survey; while not all farmers used computers the main reasons for non-use was the size of the business and a perception that the software they need does not
exist. Older farmers and smaller farms were found to be least likely to use computers and larger and mixed farms more likely to use them.

<table>
<thead>
<tr>
<th>User</th>
<th>Farmer (May be either)</th>
<th>Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decision Area</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drilling schedule</td>
<td>Variety choice</td>
<td>Optimum spray date</td>
</tr>
<tr>
<td>Spray scheduling</td>
<td></td>
<td>Optimum drilling date</td>
</tr>
<tr>
<td>Harvesting time</td>
<td></td>
<td>Extent of the problem</td>
</tr>
<tr>
<td>What crop to plant</td>
<td>Diagnosis</td>
<td></td>
</tr>
<tr>
<td>What markets</td>
<td></td>
<td>Spray rate</td>
</tr>
<tr>
<td>Cultivation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm work</td>
<td>Chemical vendor</td>
<td></td>
</tr>
<tr>
<td>scheduling</td>
<td>Safety</td>
<td></td>
</tr>
<tr>
<td><strong>Decision Type</strong></td>
<td>Scheduling decisions</td>
<td>Scientific &amp; Information based decisions</td>
</tr>
</tbody>
</table>

Figure 3.3: Showing the roles of farmers and advisers, the overlap between them and the division into scheduling and information-based decision types.

The division of responsibility for decisions was seen, by the author, to be drawn along the lines illustrated in Figure 3.3, where in general technical and information-intensive decisions are taken by consultants (of any type) and scheduling decisions are taken by the farmer. The large area of overlap in the middle however suggested that there was no clear dividing line between user types.

The strong and necessary role of the consultant was highlighted in the findings of this report. Farmers rely on consultants to provide advice on information-intensive or technical areas such as pest and disease diagnosis and chemical choice. The relationship is often built up over many years and the advice trusted to the extent that the weather rather than the consultant may be blamed for poor yields. The fear that the decision support tool would replace the role of the consultant was found to be strong in both groups and potentially detrimental to the uptake of the system.
Analysis of the interviews provided a breakdown of the factors involved in the making of each decision relating to winter wheat and the information sources used by farmers and advisers. These are described in full in the report (Appendix D). The list of potentially useful decision support facilities extracted from the results is summarised in Table 3.1.

The ideas contained within the 'scenarios' were generally well received and generated considerable feedback. The use of 'what if' facilities was seen to be a valuable tool.
Based on the results of the two surveys it was suggested that the functions and features, outlined below, comprised the key user requirements for decision support systems in winter wheat crop production.

- Access to information on: markets; varieties; seed availability; trials results; chemical manufacturer’s specification data; chemical mixes; chemical costs; availability of chemicals; and research data.
- Access to local information on: weather; trials; and variety yields.
- Increased accuracy of local weather information.
- Scientific data i.e.: compiled research results; pest and disease simulation models.
- Tools to support the integration and compilation of data.
- Tools to support sorting, cross referencing and analysing of database records.
- Financial tools to support 'What ifs' and gross margins analysis.
- Facilities to support the recording of farm data including locations of weeds, nutrient deficiencies etc. and to link to satellite information channels.
- The ability to share data between a range of applications.
- Ease of use.

These requirements were adopted during the projects 'proper' start-up meeting as the basis for the design of the DESSAC system but it was felt that further information was required to identify priorities and both to refine and expand on the data gathered in the interviews. There was also some discomfort with findings which did not fit with many of the project team members’ beliefs about the industry (e.g. that there was a low computer base).

While the numbers interviewed for the initial requirements task were reasonably large, the decision was taken to 'ratify' the findings with a much larger population and cast light on some of the other potential problem areas at the same time. In the light of the GRIME experience in a similar area, the author suggested the use of a postal survey.
3.4.3 Postal survey

The aim of the research

The postal survey followed immediately after the face-to-face interviews and, in addition to validating existing data, was designed to address the following issues:

- Limited sample size. Despite the increase in number and farm size represented by the second set of interviews there was a feeling that the results might not be representative of the farming population. In particular, it was thought not to be representative of the larger scale farmers who many felt would be the initial and main users of the DESSAC system.

- Need for specific fungicide requirements. The initial brief for the interviews was fairly broad and they consequently did not provide enough detail for the development of the specific fungicide decision support module, in particular on the information required to make good fungicide decisions.

- Need for an understanding of the broader range of farm decisions. While the focus of DESSAC was on fungicide decisions and on arable crops it was felt that the project should be aware of other decision areas.

The full report of the postal survey can be found in Appendix E.

The role of the author

At this point the project had officially started and HUSAT were the only organisation providing human factors/ergonomics input. The author's role was therefore to design, administer, analyse and report on the postal survey in full consultation with User Needs Group. There were no other HUSAT employees working on the project at this time.

Method

The survey was distributed via a mailing list (belonging to Morley Research Centre) to members of an agricultural group comprising arable farms of a variety of sizes, particularly at the larger end of the scale. Seven hundred and fifty questionnaires were distributed.
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The questionnaire was designed to determine the following:

- The profile and geographical spread of the respondent
- The type of farms they run/advise on
- The respondents potential interest in the DESSAC system.
- The respondent's computer use.
- The potential market for DESSAC and the platforms it has to support.
- The current users of computers and the extent of use by farmers & consultants.
- The uses of computers and the extent to which they are a part of farm management.
- The use of crop management software in general.
- The decision areas respondents consider important when growing winter wheat. (To validate the existing list of decision areas and to determine the most critical areas for future decision support systems.)
- The information farmers and consultants considered a) important and b) essential when making decisions about fungicide application. (To identify the specific requirements for the fungicide decision support module being developed as part of the DESSAC project.)
- The most important decisions farmers and consultants have to make with regard to the farm as a whole i.e. those most critical to its success. To identify the full range of farm decisions to ensure that the DESSAC system would sit comfortably among them.
- The source and type of weather data currently used by farmers and consultants. (To provide DESSAC with information on the type of local weather data available for use by decision support modules.)
- The use of crop consultants by farmers and their source of chemical supply. (To validate previous research findings which suggested that most farmers use a
consultant of one type or another, mostly agrochemical distributors. Also to identify the potential requirements for chemical information i.e. the existing information flows which could be supported or additional sources provided.)

- Those decision support facilities which farmers and consultants might find useful. To identify key facilities that DESSAC should aim to support or incorporate.

The questionnaires were distributed with a pre-paid addressed envelope. A 'cut off' date was set after which late-arriving questionnaires would not be included in the analysis.

**Summary of results**

Of the 750 questionnaires distributed 146 were returned by the cut off date, equating to a 19.47% return rate, which is not uncommon for a postal survey which is not followed up by personal contact (Fowler, 1989, pp. 48).

The main criticism of the earlier studies was the size of the samples and in particular the range of farm sizes they contained. This survey elicited the views of an additional 139 farmers, many of whom farmed very large areas of land. There were sufficient of these to calm the fears of those who had criticised the earlier surveys.

The survey supported the observations of increasing computer use, although the higher level of computerisation suggested by the postal survey was attributed to its self selecting nature i.e. most of those with an interest in computer technology were likely to have responded.

The decision areas indicated by the earlier survey as suitable for support were also validated by the postal survey. Those most frequently chosen by farmers as important when growing arable crops were:

- choice of effective spray date (63%);  
- choice of spray ingredient (62%);  
- choice of variety (57%);  
- fertiliser requirements (55%); and
diagnostic decisions when faced with crop damage (55.47%).

Scheduling and safety decisions (farm-based information and non-scientific) were low on the list as was choice of distributor.

The importance of crop consultants was also supported; most of the farmers who responded to the questionnaire used a crop consultant of some description. The decision areas consultants selected as important were very similar to those of the farmers with over half selecting choice of ingredient, fertiliser requirements, effective spray date and variety choice.

The facilities that farmers most frequently selected as being useful and capable of producing reasonable savings of time and money were again very close to those identified previously, however the following differences were observed. Two facilities identified in the original survey, while seen as interesting by over 50% of those responding, when scored in terms of their ability to save time or money actually fared less well. These were:

- Access to information on chemical manufacturer’s specification data.
- Tools to support sorting, cross referencing and analysing of database records.

Other facilities which were seen as less critical by the respondents to the survey were:

- Tools to support the integration and compilation of pest and disease data.
- Facilities to support mapping of field characteristics, yields, ditches, weeds etc.
- Information on seed availability.

Consultants favoured many of the same facilities as farmers; ten of the top 14 facilities were the same, however they were more interested in scientifically-based information (as suggested previously) while the farmer’s top 14 reflected financial and practical concerns.

Respondents were asked to identify the information they felt to be important and essential when making decisions about fungicide applications. There were great
similarities between the farmer and consultant responses to this question suggesting that whoever makes the decision about fungicide application, the information and support they need would be very similar.

The results of this survey also supported findings from the earlier GRIME survey that the type of local weather data collected on farms, and therefore available to incorporate into models, was fairly limited.

The question relating to whole farm decisions suggested that financial decision-making was the most common and therefore the most important to be addressed: variety choice and marketing were also seen to be particularly important.

In summary the results of the postal survey broadly supported the findings of the previous surveys. More importantly however, the exercise served to focus and prioritise the earlier more general statement of requirements and illustrated the usefulness of this type of mixed approach. The data provided a set of priorities for information for the fungicide module and additional information on the types of weather data that farmers could realistically provide. It reassured the project consortium members and members of the User Consultation Group\(^\text{11}\) that the requirements were correct and that the broad focus of the system was appropriate (although the need to support or integrate tools for the financial management of the farm was clarified as a result of the exercise).

As a result of the face-to-face and postal surveys a statement of the requirements for the software was produced (see Appendix E). The means by which this was accomplished and a discussion of the methods for requirements analysis can be found in Section 5.4.3.

\(^{11}\) The User Consultation Group comprises leading farmers and consultants and members of farming and consulting organisations. The purpose of the group is to provide a sounding board and advice panel during the development of the DESSAC system.
3.4.4 DESSAC Workshops

Aim of the research

Continual checking with users is an essential part of a user-centred design process. Having collected a large amount of data and produced a set of 'requirements' the DESSAC project needed a method of consulting with users. There were three main reasons to start checking at an early stage:

- to check that the statement of requirements produced as a result of the analysis task was an accurate reflection of the user’s needs, and
- to provide feedback on early design ideas, in the form of interface 'mock-ups' and
- to give the industry a feeling of ownership of the system by involving as many people as possible in its design.

A full report of the largest DESSAC workshop can be found in Appendix F.

The role of the author

The role of the author in this phase of the project was to be responsible for the organisation and running of a series of user workshops, the idea for which was promoted by the author after witnessing the utility of a series of ‘Focus Groups’ organised by another project in HUSAT. The analysis of the results of the workshops and their presentation in a form suitable for use by the developers was also the responsibility of the author.

Method

Face-to-face interviews are costly in research time and resources and postal surveys cannot easily be used to gain feedback on design ideas so a slightly different approach was required. A workshop/focus group forum was adopted. This provided the personal contact and richness of data required but reduced the costs to manageable proportions.

Over a period of 12 months four sets of workshops were conducted with an additional 39 users, a mixture of consultants and farmers. In order to avoid the danger of users
becoming hostages, new users were sought for each workshop - if the same people are used continually for feedback they become very familiar with the project and the researchers and are less likely to be critical (Damodaran, 1991). This has been likened to the way that hostages form bonds with those who are holding them.

Each workshop was slightly different to reflect the changes in the interface design over the year. The basic plan can be found in Appendix F which contains the full report from the first and largest set of workshops; a full synopsis of this basic structure follows:

- Introduction to the project and the purpose of the workshop
- Examination of and commenting on the user requirements specification (1st only)
- Walkthrough demonstration of the current state of the design. In this phase one person would walk the users through the various screens and ask questions such as: ‘what do you think this screen is for’, ‘how would you use it’, etc. Questions were designed to test the usability of the design and its fitness for purpose.
- General discussion

All workshops employed a semi-structured approach. Questionnaires and check-lists were used to ensure that issues considered critical by the designers were addressed but free discussion was encouraged in order that other areas of concern would not be missed. All sessions were tape recorded.

Mock-ups were generated initially by the technical partners as they explored their ideas about the form and presentation of information. Later as the ideas became too complex to mock-up quickly using programming tools the author created rapid prototypes using Macromind Director™. These were used to give users a real feel for the type of functionality they could expect from the final product. This approach was felt particularly important in projects of this kind where users have no previous experience on which to draw. Other research supports the benefits of the rapid prototyping approach; for example Gordon and Beiman (1995) who reported 39 case studies in most of which rapid prototyping was found to be a successful technique.
Summary of results

The workshops proved to be a useful and productive method of fulfilling project objectives. The participants seemed to feel that the workshops were worthwhile and much positive feedback was received (see Appendix F). They appeared to be confident that their comments had been noted, and would be acted upon, and left with a generally positive view of the DESSAC project. The utility of the prototyping approach was amply demonstrated as many of the comments could not have been generated without a concrete example.

3.4.5 User requirements specification

The aim of the research

This piece of work started on completion of the user requirements analysis and continued during the period in which the first set of workshops were being developed and run. One of the project milestones was the delivery of a ‘user requirements specification’ document. This is a document which contained the distilled requirements from the interview and survey stage and which was to be used as a record and as a reference for the technical project partners.

The aim of the research was to find a way of collating and presenting the findings from the extensive survey work which would be comprehensive and useful. The full requirements document can be found in Appendix G.

The role of the author

The role of the author was to produce the requirements specification document.

Method

The first approach to the problem was to collate the data gathered under headings of information type (see Appendix B for examples). This approach was useful in that it quickly identified the information the system had to contain and enabled the consortium
to begin the process of identifying sources of information and ways in which it could be incorporated into the system.

However, a list of the information used by crop producers and consultants when making decisions and the sources of that information was found not to give the DSS developers sufficient information. It told them little about the type of model(s) they needed to develop nor the facilities that would be required to support the decision. In short it told them very little about the way in which the decision was made and how it could be supported by a DSS. Nothing in the task analysis literature suggested a way in which the data from the surveys could be translated into a specification for a decision support system (see Chapter 5.2 for a discussion of the task analysis in relation to DSS).

Work within the GRIME project had suggested that the questions the user asked when making a decision were very important. A system which was designed to support the wrong question would be of little use even though the underlying model might be capable of answering a range of more appropriate questions. For example, one system ‘BROCCOLI’ (Wurr et al., 1995), contained a model of crop growth which used planting date and initial measurements plus weather data to predict the development of the ‘head’ of the broccoli plant. The system was developed to provide the user with information on the size of the head on a given date. Unfortunately, this information was of no value to the intended user. Had the system employed the model in a slightly different way, producing an estimate of the number of marketable heads in a given time period, it would have been used everyday by the grower’s marketing agents.

The DESSAC survey structure was therefore designed to take note of the types of question the arable farmers asked when making decisions about fungicide application on winter wheat crops. A large number of questions were gathered in this way.

The questions in their raw form however, while useful, did not provide a clear view of the requirements for the decision support tool and a means of translating them into something more concise was sought in the literature. A literature search revealed that the
importance of questions to the development of a decision support system had also been noted by Professor Bay Arinze, a management scientist (Arinze, 1992).

Arinze proposed a method for the identification of user requirements based on the central position of the user's questions or 'decision enquiries' (his term) within the DSS. This method is described in some detail in Section 5.4.1.

Arinze proposed three levels of decision enquiry: 'state' enquiries (what is/what might be the current state); action enquiries (what should I do to achieve x); and projection enquiries (what will happen if I do y). He proposed that the identification of state enquiries would permit the definition of the information requirements of a decision support system and that identification of the action and projection enquiries would define the design of the system itself (functionality and interface requirements).

The Arinze approach was eventually applied to the pool of questions generated by the DESSAC surveys. Each question was printed onto a strip of paper and all the strips were placed in the middle of a large table. The author and the head of the User Needs Group then proceeded to group the questions on a subjectively assessed like-with-like basis. The aim of the exercise was to identify and to examine groupings of questions in case they provided more direction. At this stage the Arinze categories were not consciously considered because neither participant had any evidence that they would be particularly useful (the author did however have knowledge of them and this may have influenced her grouping strategy). After approximately one hour the majority of the questions had been grouped. As an additional exercise the groupings were compared with the headings proposed by Arinze.

**Summary of results**

The match between the groupings generated by the exercise and the headings proposed by Arinze was striking. Very little re-shuffling was required to fit all the question strips into his categories. This discovery enabled the specification to proceed.
The high level groupings into which the questions fell were organised and expressed as shown in Figure 3.4.

Figure 3.4: High level questions organised according to the Arinze taxonomy
The actual questions contained under these headings were presented in the requirements document alongside the information needed to support them. Each question was ranked by two consultants as to their importance to the decision process. Rankings ran from one (‘very important’) to five (‘not important’). The ranking process was used to determine priorities for the development of utilities. An example of the table produced in this way is shown in Table 3.2.

Table 3.2: Example of question table from requirements document

**Sub question: How do I use it? (dose/timing)**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What is the most effective dose for my purpose?</td>
<td>Dose response curves</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Date of application</td>
</tr>
<tr>
<td>2</td>
<td>If I leave spray for ‘X’ days which is the best chemical/dose then?</td>
<td>Chemicals listed in eradicant activity order</td>
</tr>
<tr>
<td>1-2</td>
<td>What impact will the current weather conditions have on my spray choice,</td>
<td>Label. Pesticide register</td>
</tr>
<tr>
<td></td>
<td>decision e.g. should I put on more, or less or wait?</td>
<td>Eradicant activity of chemicals</td>
</tr>
<tr>
<td>2</td>
<td>When was the last spray date and what did I use?</td>
<td>User records</td>
</tr>
</tbody>
</table>

The ability to use these questions as a ready set of evaluation criteria during development was an additional benefit of this approach.

### 3.4.6 Validation trials

**Introduction**

The success of the DESSAC system will be measured in the number of people i.e. farmers and consultants, who buy and use it (it is due to be launched in June 2000). The project adopted a user-centred design approach to try to ensure that the final product was usable and useful and would therefore be attractive to potential users. The user requirements survey and workshop activities in the earlier part of the project ensured that
the software incorporated many of the features specifically requested by the industry but the evaluation process continues.

Unlike many pieces of commercial software, the system being developed within DESSAC is very different from anything that its users will have seen previously and there are a number of questions that can only be fully answered when the system is available for use within a realistic working context. These are:

- Can farmers/advisers use the software easily in a working context?
- Can farmers/advisers easily get answers to the questions they want to ask?
- Are the answers in the right format for the task?
- Do farmers/advisers think that the software improves performance?
- How well are the directions given by the software being followed by farmers/advisers?
- How accurate/valid are the farmers/advisers inputs to the software?

In order to provide initial answers to these questions, funding for a set of validation trials was secured. Three stages of validation were planned, to match the availability and robustness of the emerging software, these were:

- Laboratory trials (completed). Testing in the laboratory under controlled conditions to identify and remove any problems that would cause difficulties in the field.
- Short on-site evaluations (on-going - 1999). Testing in the actual work place over periods which are long enough to identify problems but not long enough to interfere with the user’s normal working patterns.
- Long-term on-site evaluations (planned – 1999-200). A sample of around 20 users will be recruited for this exercise from the DESSAC database. They will have to agree to use the software for decision-making on a named field and to be
interviewed by telephone on a regular basis. This task will also include tracer studies in which certain decisions are monitored in detail. The information used and the means by which decisions are resolved will be recorded both automatically and through interview channels.

The rest of this section reports the method and findings of the first of these three stages, the lab trials. The second and third stages will not be completed until the end of 1999 and 2000 respectively. The full report of the laboratory trials can be found in Appendix H.

The role of the author

The role of the author in the user evaluation part of the DESSAC validation trials is of project leader and creator of the evaluation process. The author and another HUSAT employee developed the laboratory trial procedure as a team and both participated in the trial organisation and management. The ultimate responsibility for the trial however lay with the author.

Method

The purpose of the laboratory trials was to test the first available working version of DESSAC with its intended end users in a controlled setting. Criteria for selection of users for these trials were that: they had no previous experience of the DESSAC system, were fungicide decision-makers, computer literate, and willing to give up one and a half hours of their time to the project. To ensure that a representative sample was obtained, three users from six key groups were required (18 in total). Table 3.3 illustrates the categories.

### Table 3.3: Categories of users within the trials:

<table>
<thead>
<tr>
<th></th>
<th>Farmers</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-300ha</td>
<td>300-800</td>
<td>800+</td>
</tr>
<tr>
<td><strong>Consultants</strong></td>
<td>Independent</td>
<td>Distributor</td>
<td>ADAS</td>
</tr>
</tbody>
</table>

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The HUSAT usability laboratory and its recording equipment were used for the trials; video equipment, monitors, a mixing desk and a VHS video recorder to record the final mixed video. The usability lab comprises two main rooms with several adjoining ante-rooms. The two main rooms are separated by a two-way mirror and a door. Figure 3.5 illustrates the room layout.

![Diagram of the HUSAT Usability Laboratory](image)

**Figure 3.5: Layout of the HUSAT Usability Laboratory**

The DESSAC system was installed on a Dan multimedia PC (300 MHz, 64Mb RAM). A hand-held micro cassette recorder was used for back-up.

Three questionnaires were designed for use during the trial for: a) gathering basic biographical data about the participant; b) answering specific system-related questions during the trial; and c) obtaining feedback from the participant after the trial. Copies of these questionnaire can be found in Appendix H. A recording sheet was also developed for use by those observing the trials.

The laboratory was staffed by two or three personnel at all times. One person guided the participant through the trials and the other(s) managed the recording equipment and made observations. Several HUSAT staff were called upon to support this activity and the roles were alternated.
Subjects who met the participation criteria were selected as outlined in Section 2.2.

As there were only certain areas of the software robust enough for hands-on use a script format was used to guide the user through the software. Users were taken on a 'walkthrough' of the functionality and layout and where possible asked to carry out tasks to enable them to have some hands-on experience. The participant was asked questions relating to each component immediately after the task or demonstration for that component. The responses were manually recorded.

At the end of the trial (duration of 60-90 minutes) the participant was asked to complete a final questionnaire.

**Summary of results**

Two of the eighteen invited participants were unable to attend, one from each of the smaller farm categories.

The overall attitude to the system was very positive. Several users stated that they would like to take the system home with them and start using it immediately. Comments included:

- 'see this as a magnificent and significant step forward'
- 'I think this program is terrific: I would like to take it home'
- 'very intuitive'
- 'good science and product combinations and weather data, all there together'
- 'has substance behind it'
- 'extremely good'
- 'reassuring to know information is being used and HGCA money is being fed back to you via DESSAC'
- 'it does exactly what it says. It's a good decision support system'
Problems were encountered, but these were largely technical and not related to the scope or direction of the system. More general negative comments concerned:

**Reliability**: reservations related to the reliability of the models and the need for them to be proven in the field. The robustness of the system was also questioned as failures could undermine the advisers' credibility with the farmer.

**Local applicability**: Participants stressed the need to be able to take local conditions, such as soil type, into account, and tweak the system to suit practical needs.

**Presentation of numerical results**: The fact that the system shows exact figures for yield and margin was seen as misleading by several participants. It was suggested that a range should be provided instead. The absence of indications of significant differences between options was also felt to be a problem.

**Reduction of adviser role**: There was a fear, among some consultants, that if farmers bought this system they would start to make their own decisions and would not need advisers in the traditional way. Instead of giving advice, they will be given shopping lists.

The results of the trials were documented under headings of: perceived usability (ease of use, utility, attitude to the software, need for training and help); specific questions posed by the technical partners (i.e. how to represent uncertainty); and a complete listing of problems relating to components of the system with solutions where possible.

In summary, the results of the trials suggested that the functionality provided by DESSAC was meeting its objective of supporting the user in making fungicide decisions. Several major hurdles to widespread acceptance were identified by the trials and are summarised as: acceptable scientific validation of the models, reliable updating of the information within the system; and the pricing of the product.
3.4.7 The display of uncertainty in the DESSAC user interface

The aim of the research

This piece of research was initiated in response to a practical problem which arose during the design of the DESSAC Wheat Disease Manager (WDM) user interface i.e. how to make the degree of uncertainty inherent in the output of the WDM models explicit and meaningful to the end user.

Uncertainty can be defined as a condition of not knowing for certain and may arise from a number of sources: statistical variation; systematic error in judgement; linguistic imprecision; inherent randomness and disagreement among experts (Cleaves, 1995). Whatever its source, awareness of uncertainty can have a strong influence on decision-making. In decision-making without uncertainty, or 'riskless' decision-making, choices between alternatives are straightforward. The decision-maker analyses the consequences of each alternative and chooses the optimum alternative for the situation. In 'risky' decision-making, or decision-making under uncertainty, it becomes much harder to determine what the 'optimum' alternative is, and the possibility of error due to inappropriate choice increases. To take good decisions under these circumstances requires that the decision-maker is made aware of the degree of uncertainty surrounding each alternative, and ideally the potential for loss associated with it.

At the heart of a decision support system lies a mathematical model and/or a rule-based representation of the decision area. Although simulation models are more flexible than their rule-based counterparts they are still, at best, an imperfect description of a highly complex set of relationships. An enormous number of variables impact on the growth and development of food crops. Even if it was possible for the average user to collect data on all of these variables, which it is not, our understanding of the dynamics of the relationships between them are still in their infancy. As it stands only the simplest relationships are modelled and only the most important variables within them are used.
To make an informed decision on the basis of information generated by a DSS, a decision-maker has to be able to assess how much trust to place in any generated alternatives. That is, for every alternative solution to a problem, the user interface should provide information on how far the models imbedded within the DSS are likely to deviate from reality.

The main aim of this research was to seek out existing guidelines for the presentation of this type of uncertainty to non-statistically trained users i.e. the most common type of user who will eventually make use of the DESSAC system. A secondary aim was the development of a taxonomy of guidelines to support future developers of DSS i.e. a continuation of the search for generic design ideas to support the rapid transfer of model from science to industry, as first discussed in Section 3.3.3.

A more detailed description of this research can be found in Appendix I.

**The role of the author**

This research was entirely initiated, researched and reported by the author.

**Method**

A comprehensive survey\(^{12}\) of the literature relating to the display of uncertainty was conducted over a period of three months. The search made use of OPAC, CD-based, and remote services (e.g. BIDS). A later investigation employed the more traditional paper-based approach to cover earlier, non digitised journal editions. In addition, questions relating to the search were posed to a range of appropriate Internet-based discussion groups. This tactic was employed when it became apparent that the conventional search was producing little of value. It seemed incredible that so little should be available and the wider discussion was initiated in the hope of generating new avenues of exploration and of picking up on as yet unpublished work.

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\(^{12}\) Over 500 documents and abstracts of papers were scanned in an effort to identify relevant materials.
**Summary of the results**

Searches of abstract databases were very disappointing, and while the discussion groups generated a large number of interesting and helpful responses they produced no additional leads. The largest number of potentially useful papers related to the long and well-argued debate about the use of graphical or tabular displays.

Only three papers of the type expected to be found in quantity were uncovered by the research. The first (Ibrekk & Morgan, 1987) related directly to the problem at hand and early discovery of its title 'Graphical Communication of Uncertain Quantities to Non-technical People' and date, 1987, led to an unwarranted surge of optimism. This paper is discussed in detail in Appendix I. The other two papers (Shackel, 1960; Herman et al., 1964) which emerged as a result of a peer review of a draft of this research for a journal publication, are less comprehensive. Another useful find was the work of Tufte (1983 & 1997) whose notion of the 'data-ink' ratio\(^\text{13}\), while not directly applicable, is a good guideline to consider for interface design. Tufte argues that the intelligibility of a graphical structure is directly related to the ratio between the quantity of ink and the amount of data on the page i.e. the higher the ratio of data to ink the more effective the graphical device.

As a result of the survey and the obvious lack of guidance on the display of uncertainty to DSS uses a two-phased classification relating to the display of uncertainty was proposed. In this approach the decision about which type of display to use is taken in two stages which are labelled: Data Source and User Question. The first stage trims the search space and the second provides the means to identify a guideline (where one exists).

\(^{13}\) The ratio of data to ink. Tufte believes that the higher the ratio of data to ink the better the display.
Figure 3.6: Showing overview of two-stage process

Figure 3.6 illustrates the relationship between the two stages that are described in detail in the following sections.

**Data Source**

On the basis of research findings by Olson & Bubescu (1997) and Budescu & Wallens (1995) it seems that uncertainty data should be represented differently depending on the precision of its source i.e. 'vague' or 'precise'. Both textual uncertainty data and numeric uncertainty data of a 'vague' type are best represented textually. This suggests that uncertainty derived from 'expert' opinion, e.g. estimates of confidence which are often represented as a number, when incorporated into decision support systems, should ideally be represented textually. This leaves uncertainty data with a precise source (resulting from external, quantified random variation, such as a simulation model) to be represented with graphs or tables. A representation of this decision matrix is presented in Figure 3.7.

---

<table>
<thead>
<tr>
<th>Stage</th>
<th>Data Source</th>
<th>Numeric</th>
<th>Textual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Representation</td>
<td>Precise/Vague</td>
<td>Vague</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Graphical/Textual/Tabular</td>
<td>Textual</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stage</th>
<th>User question – data requirement</th>
<th>Guideline for Graph display</th>
<th>Guideline for Tabular display</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>User question</td>
<td>Guideline</td>
<td>Numeric range</td>
</tr>
</tbody>
</table>
The table can be used as the first stage in the classification process and as a means of cutting down the search space when attempting to identify a solution.

The main area of choice left by this table is that of deciding between the use of a tabular and/or a graphical display for precise numeric data. This is an area on which there is no shortage of literature. However, while many papers describe the performance of graphical vs. tabular displays, the findings often conflict (Nowell, 1997). The literature most commonly suggests that a graphical format is the easiest for humans to interpret, even for small data sets (Melody Carswell & Ramzy, 1997), although some studies conclude that a mix of tabular and graphical displays produce the best performance of all (e.g. Bennet & Flach, 1992; Powers et al., 1984). Tabular displays most commonly describe uncertainty in numeric form, and as a range. Most importantly however, the commonest conclusion of the papers on this topic is the dependence of the outcome on the type of task in which the display is used (Melody Carswell, 1992; Yazici, 1995). It is the focus on task which provides the second layer of the classification system – User Questions, illustrated in Figure 3.8 and discussed in detail in Section 3.4.4.
User Questions

If the most appropriate display of data is highly task dependent, and the task unit within DSS is the question or ‘decision enquiry’ posed by the user, then the next stage in the categorisation process must be to identify common enquiries. It is possible that common sets of decision enquiries exist for the display of uncertainty. In the 1992 paper Melody Carswell identifies four common types of tasks relating to the graphical presentation of data, each of which has a number of user questions associated with it: e.g.

- Point-reading (what is the value of...?)
- Local comparisons (is x greater than y, and how much greater?)
- Global comparisons (is x+y equal to a+b, is d greater than the average of a+b)
- Synthesis (is the variability of the data points large? What might be the value of a data-point not on the graph?)

As outlined previously, the most informative paper uncovered by the search was one of only three that the survey was able to identify as dealing specifically with the display of uncertainty in numeric data. In an experimental study by Ibrekk and Morgan (1987), two types of users (non-technical and technically aware) were presented with nine graphical displays of the same data. Based on these displays ‘expert’ and ‘novice’ subjects were asked to make judgements, either with or without instructions, about events such as the depth of predicted snowfall and flood.

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The displays are shown in Figure 3.9 and were:

1. a point estimate with error bar;
2. six displays of probability density
   - (2) "discretised" display
   - (3) pie chart
   - (4) conventional
   - (5) mirror image display (devised by Ibrekk & Morgan)
   - (6) & (7) horizontal bars shaded to display density using dots or vertical lines
   - (8) a Tukey box plot; and
   - (9) a cumulative distribution function.

Six forms (2-7) of the probability density display were used because formally equivalent representations were felt not to be psychologically equivalent i.e. although they were showing the same mathematical relationships they seemed to be interpreted differently by observers.
The data indicated that questions asking for the mean were best addressed by displays one & eight, that displays four, five, six & seven seemed to lead subjects towards the mode. Subjects were most sure about their responses to displays one & two and least to five & nine. In the case of three they were often quite sure they were right even when they were wrong (a potentially dangerous result for a DSS display). Ibrekk & Morgan found that while explanations produced answers slightly closer to the mean they had little overall effect and in many cases were confusing. They also observed that a 'rusty knowledge' of statistics, a graduate degree, or use of information about uncertainty on the job, did not significantly improve subject performance.

Their conclusions echoed those of the graphical/tabular surveys in suggesting task dependence: they observed that the performance of a display largely depends on the information that the subject is trying to extract. In interpreting the data the authors noted that:

- displays which explicitly show the information needed yield the best performance;
- pie charts are potentially misleading;
- people have a tendency to select the mode rather than the mean unless the mean is explicitly marked;
- Where subjects are asked to make judgements about probability intervals in displays that do not forcefully communicate a sense of probability density, there is a tendency for them to use a linear proportion strategy equivalent to an assumption of a uniform probability density. (That is, all points along the continuum are seen as equally likely to occur. This effect has also been noted by Cleaves (1995))

The finding on the performance of experts and novices suggests that designs which support non-statistically literate users will be equally valuable to the statistically literate.

The need to show explicitly the type of information required by the user is echoed in Shackel (1960) where it is suggested that the most likely location of a submarine target is best displayed as a type of point estimate display. The area of uncertainty around the
point in this case is shown as an appropriately shaped outline (see item (a) in Figure 3.10). This type of display was designed to allow three ships, working in unison, to bracket the target vessel.

a)  

b)  c)  d)  

Figure 3.10: Displays for submarine location: display a) described by Shackel (1960); b), c) & d) Herman et al (1964)

Unfortunately this design has not been subjected to comparative testing although a similar display has. Herman et al (1964) compared the effectiveness of a conventional display of object location (item (b) in Figure 3.10) with two other designs providing additional information about the area of uncertainty associated with the point estimate. The shaded display (c) is similar in concept to displays six in the Ibrekk & Morgan study. Display (d) is an indication of the probability contours associated with 50% and 90% of the area of the probability distribution.

The task assigned to the experimental subjects was to select one of several available time stages to take action against a submerged target. The decision included a trade off between accurate decision-making and risk to the subject. As a simulated fly-over progressed the amount of uncertainty associated with the location of target decreased but danger from retaliatory fire, expressed as cost, increased. The subject’s goal was to maximise the probability of a hit and minimise the ‘cost’. Subjects were paid a financial reward according to their performance. The results of the experiment suggested that probabilistic information processing offered an improvement in performance, both probabilistic displays producing higher rewards than the point display. There was no significant difference in performance between the two probabilistic displays but the trend seemed to indicate that the contour display resulted in a higher level of reward being obtained.
Application of results to the DESSAC display problem

The data which generates the uncertainty that the Wheat Disease Manager has to display is mathematically derived and is therefore 'precise' according to the Budescu and Wallsten definition. According to the classification table proposed earlier a textual display is not therefore recommended and the design has to be either graphical or tabular. The literature suggests that, while using both may be the best solution, a graphical display is probably the best if a choice has to be made between the two. In the WDM design, screen space is at a premium and a graphical display was selected.

The next stage requires the identification of the user questions. As these formed the basis of the WDM specification document they were readily available for the design of the WDM display. The questions the graphical uncertainty display has to be able to answer to support the user in making these decisions have been identified as the following:

1. What is the most likely outcome (in terms of margin and yield) with this alternative?
2. What is the worst possible outcome (in terms of margin and yield) with this alternative?
3. What is the best possible outcome (in terms of margin and yield) with this alternative?
4. What is the size of the spread of uncertainty around the most likely outcome?
5. How does the mean and spread in this alternative compare to others?

The Ibrekk and Morgan study provides a solution to the first four questions, the fifth is addressed in Section 6.3.13. The spread of possible outcomes and the range from best to worst is best represented by mirror image or shaded bar display. The most likely value is best represented by a display which explicitly represents it. These recommendations are incorporated into the display shown in Figure 3.11.
A shaded bar has been used in preference to the mirror alternative because subjects in the Ibrekk & Morgan study felt less certain about their interpretation of mirror displays. While the probability contour display was preferred by Herman et al the nature of their task is somewhat different to that of the agricultural user. The questions the agricultural user asks are about best and worst performance for the spray programme, and comparisons of that performance with other programmes. The questions asked by subjects in the submarine experiment were concerned with a single display and they were specifically interested in the probability of hitting a target before the profitable phase of the time allotted to the task expired.

In the design solution displayed in Figure 3.11 the shaded area (green on the screen) illustrates the spread of possible outcomes and the dark triangle on the left of the display is an explicit representation of the most likely outcome.

A version of the screen was partially tested under laboratory conditions as part of the first phase of the DESSAC user validation process (described in the next section). Sixteen users, from different sectors of the potential user population were asked two questions relating to the uncertainty display: “What do you think this display is telling you?” and “Does this display give you the information you need? (mean? best case? worst case?)”.
The questions were posed during a walkthrough of the system functionality and the first question was asked prior to any explanations of the display's purpose being provided. Clarification of the displays purpose was given before the second question was presented. Out of the 16 users, 12 had no difficulty describing the display immediately. Of the four who misread the screen, only one made a potentially dangerous mistake i.e. reading the upper limit of the range as the most likely outcome. After a brief explanation all users claimed to understand and be very happy with the display layout.

3.5 HORIS

General introduction to HORIS research

HORIS stands for Horticultural Information System and the purpose of this one year MAFF Commission funded project was to develop the first of a suite of horticultural 'encyclopaedic' information systems relating specifically to brassica crops.

Brassica crops (i.e. the cabbage family) have been cultivated in the UK for a very long time and are a key crop for both internal use and export. Consequently there is a considerable amount of information relating to brassicas both in print and in the heads of biologists, consultants and others in horticulture and research. The majority of this information can be delivered in a book type, or 'encyclopaedic' format (that which can’t can be modelled and delivered within a DSS, see Section 1.2.2).

Encyclopaedic information is taken to be information which is not derived dynamically from other software but which may be static (need updating only once or twice a year) or dynamic (regularly updated). The system was intended to bring together the results of current research knowledge and best practice into a single information resource. The brassica system was to be the first of many produced by Horticultural Research International (HRI). It is based on an existing platform called Folio Views™ which had already been used to develop a set of information systems (MORIS, Morley, 1996) for the arable sector. This system, which shares many characteristics with HTML browser-based systems, supports the production of soft 'books'.

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Appendix J & K contain the report from the initial requirements exercise and the projects Final Report respectively.

*The role of the author*

The author was responsible for HUSAT contribution to this project. That is responsible for ensuring a user-centred design approach with the support of one other HUSAT employee: elicitation of requirements, resultant specification and evaluation of the product.

3.5.1 Information Requirements

*The aim of the research*

The aim of this phase of the research in HORIS was to identify the specific requirements of brassica growers and their consultants for encyclopaedic type information. As far as can be determined these requirements (i.e. the type of information growers and consultants consider to be important and useful) have not been previously documented. The extreme time pressure on growers and consultants, particularly during the peak growing season, makes it particularly important to deliver and present information in the most effective and useful way. These people simply do not have the time to filter through a great deal of irrelevant material to locate something of interest. Although the decision had been taken to base the HORIS system on its arable counterpart 'MORIS' (MORley Information System), no usability evaluation of MORIS had been undertaken and there was no means of determining whether the layout and structure were suitable for a horticultural audience. Full details of the results can be found in Appendix J.

*The role of the author*

The author was responsible for the design, implementation, analysis and delivery of results for the Information Requirements phase of the project with support from another member of HUSAT staff.
Method

The usual two methods were used to elicit requirements (postal questionnaire and workshop/focus group) as both had proved useful and effective in the DESSAC and GRIME projects. Postal surveys were employed in order to reach a large number of people in a short period of time and to get quantifiable answers to simple questions. Focus groups/ workshops were used to provide richer data for the requirements analysis.

Two hundred and fifty questionnaires were distributed to a mix of brassica growers and consultants whose names were provided from HUSAT and HRI mailing lists. The questionnaire included the following topics.

- Location of enterprise.
- Size of enterprise (hectares farmed or consulted on)
- Number of hectares devoted to brassica production
- Computer capability
- Brassica crops grown
- Information required (respondent selected, from a checklist of information types, information they thought would be either an essential or interesting part of a brassica information system. Space was left for additional categories to be introduced by the respondents.)

Workshops comprising six to eight potential users were also planned. A form was sent out with the postal questionnaire asking people if they would like to attend one of four potential sessions. The form of the sessions was planned to be:

- Introduction to the project
- Feedback on the questionnaire results
Chapter 3

- 'Brainstorm' on requirements for most popular information categories i.e. what specific questions are the users looking to answer under the information headings; what sources of information so they currently use.

- Review of MORIS i.e. walkthrough the system explaining the concepts and content and asking for feedback on the information content and format in relation to the future brassica system. Users were given the chance to 'play' with the system themselves and to make additional comments.

- Summary of requirements

**Summary of results**

**Postal survey**

Of the 250 questionnaires posted there were 66 responses, equating to a return rate of 27.5%. Of the total 43 were farmers and 23 were consultants. The key brassica growing areas were well represented in the returns and there were a broad range of farm sizes.

Most of the consultants owned computer systems with the recommended requirements for Folio Views (20 out of 23 respondents) and over 50% of the grower respondents.

Cabbage and cauliflower seemed to be the most commonly grown brassicas although sprouts and swede were produced by over 30% of the growers. The number growing swede was less than 20%. The consultants appear to advise on all of the crops in roughly equal proportions.

While all of the sample was used to look at computer requirements and distribution of farms the numbers used to determine the information requirements were restricted to those who grow or manage the brassica crops specifically mentioned in the questionnaire. This reduced the numbers to 41 growers and 18 consultants, a total information set of 59 people.

The information requirements were ranked in order of their importance i.e. ranked according to the number of growers who felt the information was essential.

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The most popular choices were concerned with the chemical control of problems and the general use of chemicals. Identification of pest, disease and nutritional problems were also seen as essential by a high percentage of users. Growers and consultants produced similar responses although consultants were more interested in information about crop scheduling than growers and less interested in identification of problems and nutritional information.

Workshops

The response to the request for participants was less than that anticipated. Only two sessions of four and three people were conducted. However these produced a remarkable uniformity of views considering that the groups were mixed (five growers and two consultants).

The results of the discussions were summarised under the information headings which emerged from the day. Full details can be found in Appendix J. The main headings were:

- Control of pests, diseases, weeds and nutritional deficiencies: Both groups seemed to feel that the requirements for all problem areas were similar enough to group them together. Information about the control of problems appeared to be the major requirements for all participants.

- Identification of pests, diseases, weeds and nutritional deficiencies: After control, identification of problem areas seemed to be the next most essential area in which support is required. Information on all brassica pests, diseases, nutritional problems was felt to be necessary.

- Variety information: Information on varieties was felt to be useful by most of the participants.

A number of comments on the structure of the system were collated from the MORIS walkthrough. The participants thought the system should have a:
Chapter 3

- simple and easy to access structure;
- structure which avoids the need to scroll through a lot of information;
- most detailed information at lowest level;
- the crop name as a good top level.

The survey concluded that the information requirements for the HORIS system were quite straightforward; both the postal survey and the workshops agreed that control and identification of brassica problems were the key types of information the system should provide, with the addition of information on varieties. The development of a 'yellow pages' of contacts was also considered to be very useful by most users.

The control information provided by MORIS was considered to be appropriate for the purpose but users wanted photographs to be the primary method of identification within the brassica system. They also felt that the brassica system should be more structured with the most detailed information stored at the lowest level. Information could be stored according to crop but users wanted to search on more than one crop or topic.

3.5.2 Validation Workshop

The aim of the research

As a result of the requirements analysis and evaluation of the MORIS system the horticultural system HORIS was specified and created. The layout and content of HORIS followed as closely as was possible the suggestions made as a result of the requirements exercise. The development of the prototype system was conducted by HRI. The final task of this short project was to evaluate the prototype system and leave enough time for the results of this evaluation to be incorporated in the released version. The date for the launch of the system was fixed to coincide with one of the industry's major shows. Although ideally more than one iteration is desirable in a user-centred design approach the author felt it appropriate to stick to a single iteration for the following reasons:
• the project was of a particularly short duration and it would have been extremely hard to include another iteration.

• the bulk of the time available to the project would be taken up by information gathering and entry

• one iteration had effectively taken place in that the users in the initial workshops had the MORIS system on which to comment.

The primary aim of the workshops was to gain feedback on the information within HORIS, and on its presentation; to check the project's interpretation of the initial user requirements and the design decisions taken. A secondary aim of the workshops was to publicise the development of the software and to gain some measure of its likely uptake.

A full record of the workshops can be found in Appendix K.

The role of the author

The author was responsible for the design, implementation, analysis and delivery of results for the evaluation task of the project with support from another member of HUSAT staff.

Method

A workshop method was used to evaluate the prototype HORIS software, as in the earlier studies. A representative range of users were invited to attend one of seven sessions over a four day period, each session being set aside for one 'type' of user group i.e. grower or consultant. The initial plan was for at least two each of grower, consultant and seed merchant groups, each group containing seven or eight participants. This number of participants per session was, based on past experience, considered optimum to balance the requirement for maximum exposure and the need to ensure that each person felt able to participate fully.

Each of the sessions was designed to last 2.5 hours. The timetable included:
Introduction to the project (as a group).

Explanation of the software (at the two or three available machines).

Task-directed use of HORIS. Users asked to find the answers to 20 questions, to ensure that they become familiar with the informational layout of the system and with the methods of finding information.

Free 'play'

Questionnaire about the ease of use and utility of the HORIS software

Collation, confirmation and prioritisation of key issues. Full group session.

Questionnaire about the perceived quality of the workshops

Summary of results

Only six of the seven workshop sessions went ahead as planned because of a poor response for the Wednesday afternoon session on the 25th June. A total of 27 people participated overall. The full set of results can be found in Appendix K.

The main impression from the workshops was that the HORIS software was considered to be a timely and useful package for a range of users within the brassica sector. Aspects which seemed to provide the most 'added value' were the inclusion of SOLA's (Specific Off Label Approvals) in a form which would be considered legal, and access to up-to-date and accurate information on chemicals and their use.

The trials were however intended to highlight those aspects of the system which were not optimum, and therefore allow improvements prior to commercial release. The main problems identified by the users were largely related to navigation and content. Some comments were directed at the Folio Views™ shell and were therefore harder to address although recommendations were made.

Navigation problems related particularly to links and headings e.g. there were simply not enough links between related subjects. Comments or points made by the users but not
considered to be as important or time critical were also included in the recommendation report.

There was a general problem relating to the structure of the shell and the, mostly 'psychological', limitations that it imposed. The Folio Views™ software combines the attributes of a book and an electronic hyper-linked document. Given the limitations associated with a book structure and the increasing familiarity of the user population with web browsers it was recommended that the structure and linking of the 'book' were reconsidered to make them closer to Web pages.

While most of those involved in the workshops felt that the information HORIS contained was pitched at about the right level, there were many suggestions for increasing the scope of the content.

The utility of the chemical and variety information depends to a great extent on the faith that users have in its accuracy, completeness and relevance. It was therefore suggested that the software provide indicators of the source of material and the date of each chemical and variety related entry.

In conclusion, the exercise indicated that the software to a large extent met the requirements identified by the users in the earlier part of the project. Changes to the structure and content of the brassica manual identified within the workshops would however increase the software's attractiveness to its target audience as well as improve its general usability. The workshops themselves were seen to be a valuable means of collecting user's views on the software.
3.6 TIM MODELLING WORKSHOPS

Aims of the research

The TIM (Technology transfer In Models) project was a short, one year MAFF Commission funded project with a mixture of aims related to the use of model-based DSS. The stated objectives of the project were to:

- Determine the economic feasibility of a range of different approaches to the collation of meteorological data and provision of information to growers and consultants from model-based decision support systems; and

- Develop a generic framework within which computer models can be adopted rapidly by the horticultural industry, through an interactive process with end-users, to determine output-formats most suited to growers needs.

The first objective was the responsibility of Horticultural Research International and the second the responsibility of HUSAT.

A less general statement of the aims of the TIM project as far as the HUSAT component is concerned is as follows. The DESSAC and GRIME requirements exercises (Sections 3.3.2 & 3.4.2) revealed that growers and their advisers have a significant need for information about pest and disease life-cycles and response to pesticides. As was suggested in Section 1.4.2 these needs can potentially be met by the next generation of model-based decision support systems (DSS).

Unfortunately, there is a lack of understanding within the crop producing community of the scope and value of model-based decision support systems. People simply do not understand the potential uses nor, just as important, the limitations of model-based systems. There is also a corresponding lack of understanding on the part of the research institutes about the specific requirements of the industry for this type of software.
The aim of the research conducted by HUSAT was therefore to develop a mechanism by which both difficulties might be resolved i.e. the industry could be made aware of the nature of model-based systems (i.e. DSS) and in turn feed their requirements for such systems back to the science institutes.

Two target groups were chosen for the development of this mechanism. These were the brassica sector and the top fruit sector (apples & pears). These groups were chosen because they represented very different sectors in which modelling and DSS development had already taken place.

The full report from the TIM project can be found in Appendix L.

*The role of the author*

The author designed the workshop structure as a result of meetings with other members of the project team. The author was also responsible, with the support of another HUSAT employee, for ensuring the organisation and delivery of the workshops and the analysis and delivery of the results.

*Method*

The specific objectives identified within the project were:

1. Conduct a formal financial appraisal to assess the costs and benefits of a range of scenarios for data collection and information provision that are required for the implementation of model-based decision support systems.

2. Develop training tools for showing growers and advisers the potential benefits of model-based decision support systems.

3. Improve awareness of the benefits of model-based decision support systems to growers and advisers within UK horticulture through structured workshops.

4. Identify the output requirements of growers and their consultants for model-based information.
5 Determine the economic viability of an ongoing service to provide the model-based information to growers and advisers.

The third objective, the use of structured workshops to improve awareness of the benefits of model-based decision support systems to growers and advisers within UK horticulture was also utilised to support objectives one, four and five. The workshop method was seen as the most appropriate and cost effective means of fulfilling these objectives. The structure of a workshop could be made generic and flexible to enable it to be applied in any number of sectors and in a variety of situations and formats.

The purpose of the workshops was threefold:

- To determine what growers and consultants required from models.
- To inform growers and advisers of the concept and potential of computer-based models.
- To assess the perceived monetary value of predictive models to the horticultural enterprise.

The workshop was divided into three main sections, each dealing with one of the objectives listed above. Session A was designed to explore the participants requirements for scientific support and to show where models might be able to help and where they could definitely not be of use. Session B was designed to give participants an overview of the nature of models, the process by which they were developed and their strengths and weaknesses. These sessions needed to cover a set of key features (identified during discussions with the scientists) to counter misconceptions and provide a realistic assessment of the function and use of model-based software. The session also needed to be tailored to a particular sector (in this case either brassicas or apples/pears) to make it meaningful to them. Chosen guest speakers were given the key points and asked to develop a talk around them within the context of their own speciality. Session C was designed to elicit a view from the participants of the value of model-based software now and in a couple of potential future scenarios i.e. when the financial cost of using pesticides would be far greater than it is now. The workshops were designed to last a
total of no more than three hours, enabling the organisers to fit two into a single day if required.

Two simple questionnaires were developed, one to identify the participant's level of experience with models and their expectations of the session prior to its commencement. The second examined the value placed on the workshop by the participants, their understanding of the value of models and the areas in which they felt models would be of most use to them.

The key points which served as the basis for the guest lectures were identified during a brainstorming session of project members led by the author. The main points were:

- Defining exactly what is meant by a model - complex and simple models - a common definition.
  - simple models, linked simple models and complex models
  - why sometimes only a small part of the whole system need be modelled to provide useful answers
  - why sometimes a much larger part of the system needs to be modelled to provide a useful answer

- Confidence in models
  - Loss of accuracy that may occur as a result of increasing complexity
  - Validation, how models differ in the extent to which they have been validated.

- Accuracy of models (probability and distributions)
  - Problem of extremes not being as accurate as central values

- How far into the future is the model reliable?
  - Variation within populations, geographical/spatial variation.

- Benefits of models
  - Maintaining or increasing quality
  - Maintaining or reducing cost
- Reducing environmental impact

- Use previously elicited problems to show where models of benefit and how.


For Session C a set of scenarios and cost benefit tables were developed by HRI Wellesbourne, see Appendix L.

The session started with a general introduction lasting no more than five minutes, in which the shape of the session was described. Participants were then asked to spend a further five minutes completing the pre-workshop questionnaire.

Session A began by dividing the group up into smaller groups and spending some time identifying areas in which participants felt they could be better supported by the research institutes. Participants were asked to identify specific questions they had difficulty answering. These questions were brought back into a main group discussion in which they were sorted and prioritised. The ability of models to answer the participants questions was described and existing models were used as examples. This session lasted 50 minutes.

In Session B the guest lecturer went through the points identified as critical, within the context of his or her own specialised subject. Time was made available after this session for questions.

In Session C the participants were split into two groups, each with a facilitator, and asked to work through the implications of a) the imposition of a 100% agrochemical tax imposed over two years, or b)a mandatory agrochemical reduction programme achieving a 50% reduction within two years. Each scenario was worked through twice, firstly presuming limited access to predictive models and the meteorological data to run them, and then presuming easy access to predictive models and the meteorological data to run them. A sheet was given for each situation for the group to enter the financial implications of each scenario. The groups then came back together and the results of the
different scenarios were reported and discussed further. The discussions were taped for
later analysis.

The workshop ended with another questionnaire.

**Summary of results**

Attendance for the workshops was generally poor, ten users participating in each session. This was largely attributed to confusion over the term 'model' used in the invitation letters, many growers not understanding that the sessions were of any possible interest to them. Just over half of the attendees (18/32) who answered the questions stated that they had used models before.

The structure of the workshop worked well, 32 of the 33 attendees rating the organisation as 'good' or 'very good'. Twenty-one of the 33 attendees felt they had received enough information from the workshop, and 29 felt that they were able to comment fully; those were not entirely happy were most concerned about the lack of time to explore issues with HRI scientists and to ask questions.

Thirty of the 33 attendees rated themselves as either 'positive' or 'very positive' about the usefulness of models based on their experiences within the workshop, and 26 people said they could see themselves using them.

Changes to the format suggested by participants were largely concerned with the limited time they had for discussion. This was largely due to the inclusion of Session C. Session C would not be part of any future workshop as its purpose was to obtain some specific cost-benefit information for project purposes. Another area of concern was the lack of information about the content of the workshop available to participants prior to the event. Considerable confusion about the word 'model' was experienced.

In conclusion the basic structure of the workshop in sessions A and B worked very well as a two way transfer process. Participants were engaged in the process of identifying useful areas for model development and found the 'guest lectures' informative and
useful. The basic structure for the 'guest lecture' worked well although there was a tendency of the lecturer to get involved in their own interests and forget some of the brief. The project concluded that use of this method to educate the grower and farmer population was feasible and highly desirable if model-based DSS were to be taken up and used effectively within the industry.
Chapter 4

4.0 BARRIERS TO USING DSS IN CROP PRODUCTION

In Chapter 1.0 the potential for use of DSS as technology transfer tools for crop production was discussed. This chapter examines the actual use of these systems in the sector and the reasons for their apparent lack of success.

4.1 POOR TAKE UP OF DSS IN AGRICULTURE

In Chapter 1 it was argued that decision support systems are potentially useful tools for technology transfer within crop production. The reasons for this can be summarised under three headings:

- support for the filtering and delivery of practical and appropriate information in an age of information overload
- provision of a means of transferring technology in an industry which no longer has a public extension service (i.e. a system of freely delivering scientific knowledge and advice through a mechanism such as ADAS)
- offering a means of improving the level of decision-making within an industry that is being pressured to reduce and justify its chemical use.

However, although considerable effort has gone into the creation of DSS of all kinds in a large number of crop-producing countries, very few have been observed in common use on the farm (e.g. Cole, 1995). The question is why? Observation of the few systems which the author had come into personal contact with suggested that a lack of usability might be one of the key reasons for their absence on the farm. It was however possible that the answer was very simple: that few if any systems were actually available for sale or use in the UK.

Finding out about the availability of DSS in the UK was not easy as most were developed within small groups, within any of a dozen research institutes and, to date, have largely been advertised (if at all) to specific user groups through private user-institute communications channels (e.g. interest groups). Contacting each and every research group in all research institutes in the UK was a formidable and unrealistic task and another method was sought. The growth of the Internet and the use of email-based
discussion groups provided an answer. Most DSS contain models (see Section 1.3.2) and modelling is an activity in which only a small number of biologists actually engage. The author observed that quite a number of those who were known to be active in UK modelling and DSS development subscribed to an email-based discussion group called Agmodels. This group was therefore used as a mechanism to carry out an email survey (Parker, 1996) which is described in detail below.

4.1.1 DSS available in the UK

<table>
<thead>
<tr>
<th>Title</th>
<th>Purpose</th>
<th>Producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADCOST</td>
<td>To calculate the performance and annual cost of owning and running an anaerobic digester for slurry treatment and methane production</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>ADEM</td>
<td>Apple disease prediction</td>
<td>HRI East Malling</td>
</tr>
<tr>
<td>ARABLE</td>
<td>A labour and machinery planning program</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>BROCCOLI</td>
<td>A maturity prediction system for six varieties of Broccoli using meteorological and crop data.</td>
<td>HRI Wellesbourne</td>
</tr>
<tr>
<td>COST</td>
<td>To calculate the annual cost of farm machinery.</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>COW</td>
<td>To evaluate dairy cow feeding systems.</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>DRIER</td>
<td>To calculate the cost of high temperature drying</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>FUNGIC</td>
<td>A crop growth simulation which demonstrates the effect of applications of nitrogen and fungicides to a cereal crop on the progress of disease and the final yield.</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>HARV</td>
<td>To calculate the cost of combine harvesting.</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>HARDRY</td>
<td>To calculate the cost of combine harvesting and high temperature drying.</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>NCYCLE</td>
<td>A tool for balancing nitrogen inputs and outputs to a farm on an annual basis</td>
<td>North Wyke Research Station</td>
</tr>
<tr>
<td>NEARAM</td>
<td>To simulate near ambient temperature drying.</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>PEST-MAN</td>
<td>DSS for top fruit insect pest management.</td>
<td>HRI East Malling</td>
</tr>
<tr>
<td>PLAN</td>
<td>To plan the use of labour and machinery. Predicts the seeding rate in each row of carrot or red beet crops to maximise the yield in marketable grade sizes.</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>SPACING</td>
<td>To calculate the effect of logistics on spraying work rate.</td>
<td>HRI Wellesbourne</td>
</tr>
<tr>
<td>SPRAY</td>
<td>To predict tractor work rates.</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>TRAC</td>
<td>To predict the effect of transport on system work rate.</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>WATER</td>
<td>To compare irrigation strategies.</td>
<td>Silsoe Research Institute</td>
</tr>
<tr>
<td>WELLN</td>
<td>Predicting the amount of nitrogen fertiliser required to maximise a variety of crop yields</td>
<td>HRI Wellesbourne</td>
</tr>
</tbody>
</table>
The email discussion group ‘Agmodels’ was selected as the forum for the survey on the basis that the main DSS producing research institutes were represented amongst its subscribers and that there was a sufficiently large membership to identify other systems produced by smaller organisations. A copy of the initial request and description of the results can be seen in Appendix M.

Agmodel subscribers were asked to list any DSS they were aware of which were publicly available in the UK. There were over 20 responses from sites within and outside of the UK and a list of DSS was compiled. Those DSS produced and available within the UK can be seen in Table 4.1. Systems which were produced in other countries and potentially available to UK industry were also listed and can also be seen in Appendix M.

4.1.2 Non-use of DSS in UK crop production

The topics covered by the decision support tools listed in Table 4.1 are quite diverse and potentially of great value to the farmer and consultant alike. In fact many are related to financial planning of one sort or another, items which were at the top of the 'wish list' generated by the DESSAC survey discussed in Section 3.4.3. Actual figures for use were not available but personal communication with developers and discussions with farmers and consultants suggested that, at the time of the email survey, none of the listed systems could claim more than a handful of users.

Why, given the obvious potential of the technology, was this so? Are DSS simply not suitable for the agricultural environment? Agricultural IT conference proceedings contain many descriptions of systems, the majority of which never appear in any written publication again and are rarely seen in use on the farm or in the consultant's office.

4.2 Reasons for the failure of DSS

General research into DSS has suggested that current systems of all kinds are not going far enough in support of the user, see Section 1.3.5 for a discussion. Radermacher (1994), suggests that most DSS 'have a surprising emphasis on low level support', allowing simple manipulations and visualisations of data. He feels that DSS should make suggestions about what to do and present a choice of optimal solutions if at all possible. He also feels they should be capable of finding hidden dependencies in data and helping users find their preferences in a multi-attribute decision situation. This level of support, the paper suggests, employing 'sophisticated model-based background reasoning' is only
what 'a user might and should expect from systems that call themselves 'decision support systems''

But what are the reasons for the failure of DSS in agriculture? Is it simply the case that current systems don't go far enough as the general research suggests? Answering this question is unfortunately not straightforward. Most DSS developments are not published in journals, are not available in PC stores, and while there are many descriptions in conference proceedings, they tend to relate to the development and launch of the system. Few researchers are brave enough to examine publicly the reasons for the failure of their own software. Experience in the sector suggested a number of possible causes, but to take a more objective approach the available literature was trawled for other author's viewpoints. The possible reasons for the success, or failure, of their own (and other's) projects were collated and are listed in Table 4.2.

<table>
<thead>
<tr>
<th>Issue</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer ownership &amp; use on farms</td>
<td>Claustriax, 1992; Cox, 1996; Palmer, 1992</td>
</tr>
<tr>
<td>Use of models</td>
<td>Cox, 1996; Sciefer, 1992</td>
</tr>
<tr>
<td>Data requirements</td>
<td>Cox, 1996; Claustriax, 1992; Lorgeou &amp; Waksman, 1997; Moncreieff &amp; Li, 1992; Pedersen et al., 1997; Putten et al., 1992</td>
</tr>
<tr>
<td>Integration between systems</td>
<td>Andersen et al., 1992; Berlo, 1993; Claustriax, 1992; Cox, 1996; Gelb &amp; Deaman, 1992; Jorgensen et al., 1992; Lay, 1997; Pedersen et al., 1997; Steffe, 1997; Udove, 1997</td>
</tr>
<tr>
<td>Confidence in results/ training</td>
<td>Calouro et al., 1992; Levallois, 1992; Lorgeou &amp; Waksman, 1997; Mainland, 1994</td>
</tr>
<tr>
<td>Choice of user</td>
<td>Cox, 1996; Hennen et al., 1992; Jorgensen et al., 1992</td>
</tr>
<tr>
<td>Tailoring of systems</td>
<td>Claustriax, 1992; Hennen et al., 1992; Levallois, 1992; Palmer, 1992</td>
</tr>
<tr>
<td>User interface</td>
<td>Andersen et al., 1992; Calouro, 1992; Claustriax, 1992; Cox, 1996; Lay, 1997; Levallois, 1992; Sciefer, 1992</td>
</tr>
<tr>
<td>Time commitment</td>
<td>Andersen et al., 1992; Calouro et al., 1992; Putten et al., 1992</td>
</tr>
<tr>
<td>Updation</td>
<td>Claustriax, 1992; Hennen et al., 1992</td>
</tr>
<tr>
<td>User-centred Design &amp; task fit</td>
<td>Andersen et al., 1992; CDER, 1992; Cox, 1996; Gelb &amp; Deaman, 1992; Jorgensen et al, 1992; Pedersen et al., 1997; Putten et al., 1992; Sciefer, 1992; Steffe, 1997; Van der Maas, 1992</td>
</tr>
</tbody>
</table>
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The rest of this section discusses the reasons behind, and continued relevance of, these issues for the development of DSS.

4.2.1 Computer ownership & use on farms

The lack of a suitable computer base within the agricultural community has been one of the strongest arguments against the development of computer-based farm software. It is certainly true that the industry has been slow to computerise and the lack of a broad computer base was probably the primary barrier to the uptake of the earliest DSS. Recent surveys however have suggested that the use of computers is increasing rapidly (Parker, 1994; Parker et al. 1994, Parker et al. 1994a) particularly among the larger units. Taking the gradual flow of computer technology into the market brought about by advertising, education, training, the drop in prices, and the influence of new college graduates, and adding in the trend toward larger 'agribusiness's' (Technology Foresight Panel on Agriculture, 1995), it would be hard to suggest that there is no place on the farm of the next century for computer-based systems. Small farms that are unlikely to own computers are usually dependent for decision-making expertise on consultants who do. The increase in agricultural software and agricultural Internet Service Providers also suggests that there is a market out there.

For DSS to be adopted they have to be used by decision-makers. It has been argued that, even where computers do exist on farms, they are used by secretarial staff and not by farmers or consultants. Although word processing and accounts are indeed the most popular packages on computers, the potential and willingness to use DSS by farmers and consultants has been indicated by surveys in both arable and horticultural sectors (for example, 84% of arable farmers who owned computers said they used the computer themselves (Parker 1995b)). These surveys also suggested that farmers and consultants are willing to adopt the technology if it offers them a usable, useful and cost effective technique for improving their decision-making.
4.2.2 Usefulness of models

The definition of DSS given in the introduction encompasses the large number of agricultural DSS based around a biological model of some kind. The inclusion of inappropriate models in systems designed to support farmers is one of the main reasons cited by Cox (1996) in his detailed examination of the topic, for the failure of early Australian DSS technology. Cox's paper argues that the inclusion of models was an example of category mistake where process models, developed as part of professional research, are confused with model-based decision support systems, designed as a guide to action. It is certainly true that many existing systems which sell themselves as decision support tools are little more than research models with a user interface tacked on top of them. That this is true in the UK is supported by Woodwards who during an email discussion on the topic of DSS stated:

"I visited the UK briefly this year (May, June 1995) and touring around several research centres I was shown a number of 'DSS' programmes. Almost without exception these were research models that had had a little bit of interface added on. Usually there were pages of parameters to be filled in." (Woodwards, 1995)

Further support for this view is provided by Laurenson who notes that

"software developed to help scientists understand biological processes is rarely suitable for grower use. One tool is concerned with flexibility and analysis, whereas the other needs to be easy to use as part of a management routine. These two forces are diametrically opposed. The ideal scientists tool would have a knob for every variable, whereas the ideal grower tool would have none!" (Laurenson, 1999)

This is not to say that research models should be removed from support tools for the industry but that their purpose on the farm or for the consultant should be evaluated before they are included. This evaluation may then require some 'deconstruction', in Cox's terms, of the model, to avoid 'over engineering' the final product. In other words, as Laurenson (op cit.) suggests, many of the knobs and buttons have to be removed to make it acceptable as a management tool.
Although the failure of past DSS has been attributed to the inclusion of inappropriate models, many DSS have not got past the starting block because of the difficulty of developing models, integrating them to form a useful tool, and getting them inside a DSS.

Mathematical modelling of biological systems is a relatively recent phenomenon, made possible largely because of the advent of modern computer technology. Calculations impossible to undertake by hand and extremely expensive in old computing terms became feasible and even simple with the massive increase in processor speed and available RAM. However while a number of scientists have developed their models using software, the degree of programming ability varies enormously between individuals and the code is often very hard for anyone but the developer to understand. The scientist is rarely the person asked to develop the DSS; they have neither the time, the skills, or the inclination and it is extremely difficult for an outsider to integrate models developed in this way. The models may be potentially useful to the industry but the way in which they are coded has been a distinct barrier to their incorporation in DSS.

Because of the need to understand programming and mathematics as well as biology very few scientists have become involved in modelling, although the trend appears to be changing. This acts as a barrier to DSS in that much existing knowledge is not being encapsulated in this appropriate and useful form. Furthermore the act of modelling also casts light on the gaps in understanding and the development of the more complex and more useful models has been held up until these gaps have been filled.

The production of realistic and accurate DSS requires the integration of existing biological models of plant, pest and disease behaviour. For example, to determine accurately whether there will be an infection event for a disease such as Alternaria, models of spore production and infection (which themselves relate to temperature) have to be integrated with each other. Temperature determines the rate of spore production, but wet weather is required for the disease to travel from leaf to leaf by rain-splash. For crops such as brussels sprouts a further level of integration is required. The disease creates spots which, if found on the sprout buttons even in small quantities, reduce the
crop's market value considerably. If the disease occurs at this level early in the season no action need be taken but if it occurs later on, it becomes a matter of some importance. The inclusion of another model of growth stages into the disease prediction model is therefore a useful next step. Unfortunately, until recently, no tools existed to support the integration of these complex models. In the DESSAC system, for example, which contains models of growth stage, disease development and chemical efficacy over time and in relation to temperature and rainfall, links between model components are all hard coded (i.e. they are not easily separable).

4.2.3 Data requirements

Decision Support Systems have to have information about the current state of the world in order to provide the user with input for decision-making. The requirement this places on the user to gather and enter data has been cited by Cox among others (see Table 4.1) as another factor contributing to the failure of decision support tools in agriculture. Models which run quite happily in research environments are not guaranteed to meet with the same success in farm use where conditions are more variable, time to use the model is limited and logging equipment is less available and less sophisticated. The main data requirement within a simulation model is for weather information. Until very recently the only means of obtaining local weather data on the farm (and thus gaining locally applicable results) was to invest in an often prohibitively expensive meteorological monitoring device, locate it in the most typical of fields and download the data by hand. Postal surveys conducted as part of the GRIME\textsuperscript{14} (GRaphical Integrated Modelling Environment) and DESSAC\textsuperscript{15} (Decision Support System for Arable Crops) projects found that in the UK very little data is available on the farm and that which does exist is largely min-max. temperatures and rainfall (see Table 4.3).

\textsuperscript{14}GRIME (GRaphical Integrated Modelling Environment). MAFF Open Contract (OC-9206). See Section 3.4

\textsuperscript{15}DESSAC (Decision Support System for Arable Crops) Arable LINK project. See Section 3.5
Table 4.3: Weather data available on arable and brassica farms

<table>
<thead>
<tr>
<th>Data type</th>
<th>Growers (GRIME)</th>
<th>Farmers (DESSAC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(% of 72 respondents)</td>
<td>(% of 139 respondents)</td>
</tr>
<tr>
<td></td>
<td>Collected on farm</td>
<td>From Met Office</td>
</tr>
<tr>
<td>Rainfall</td>
<td>43.06</td>
<td>16.67</td>
</tr>
<tr>
<td>Min/max temp</td>
<td>10.80</td>
<td>12.50</td>
</tr>
<tr>
<td>Windspeed</td>
<td>5.76</td>
<td>11.11</td>
</tr>
<tr>
<td>Temp</td>
<td>5.04</td>
<td>-</td>
</tr>
<tr>
<td>Solar radiation</td>
<td>1.44</td>
<td>1.39</td>
</tr>
<tr>
<td>Wind direction</td>
<td>1.44</td>
<td>1.39</td>
</tr>
<tr>
<td>Pressure</td>
<td>0.72</td>
<td>-</td>
</tr>
<tr>
<td>Soil temp</td>
<td>0.72</td>
<td>-</td>
</tr>
<tr>
<td>Humidity</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

It is not hard to see why, in the few, high-intensity months when such systems are of most potential use, only the most devoted followers of science are tempted by decision support tools requiring this type of input. The alternative is to use regional data, and the resulting loss of accuracy has led to a belief in some farmers' minds that models cannot be tailored to local conditions (Parker, 1994). In the last few years however, developments in monitoring technology have led to a number of solutions which may alleviate or remove this problem. A number of systems now exist which are capable of downloading their data automatically to a central database (e.g. Hardie Metpole™); monitors have become smaller; have reduced in price; and some are capable of being ‘piggy-backed’ to form wide networks of monitors all feeding in to a common source (e.g. Adcon™). This latter solution has been adopted by European growers (Martin, 1996), has proved very successful in New Zealand (Laurenson, 1994) and is currently being tested by fruit growers in the South of the UK (Laurenson & Cross, 1997). It is conceivable that, in the near future, collaboration between interested parties and the development of better interpolation algorithms will mean that, for a price, any grower will be able to access on-line local weather data.
4.2.4 Integration between systems

In his paper Cox also suggests that decision-making in crop production in most cases is so well structured that standard algorithms are sufficient, and that the use of DSS is an over sophisticated solution. It can be argued that while this may be true of some specific problems where the user is happy with an answer which is 'roughly correct', there are classes of problems where there are difficulties with this totally algorithmic approach.

Firstly, much of farm decision-making is made up of many interlinked decisions. For example, the optimal spray date for one crop in one field has to be balanced against: the requirements of the rest of the farm; the pressure on machinery; the availability of staff; the potential for a change in the weather; etc. It is this balancing act, with ‘more than a headfull of data’, which gives farm decision-making its semi-structured appearance and which therefore makes it suitable for computer-based decision support (Curtis, 1989). This does mean, however, that to be successful, a DSS has to provide extremely useful and pivotal information to counter the time taken in learning and interrogating it during peak months of the year, when the results have still to be integrated with all other associated activities.

The importance of integration between supporting systems on the farm has been highlighted by a number of other authors, notably those involved in the Danish Integrated Farm Management System (Andersen et al., 1992) which ended in 1991 and at its peak had 250 subscribers. The Danish system provided access to all the programs used by advisers and one of the key lessons they learned from the experience was that

‘if farmers are to use the system it is necessary to integrate the different sectors in a coherent system for the whole farm’ (Andersen et al., 1992. p.5)

A more recent Danish initiative, providing support for winter wheat management, started from this basis (Olensen et al., 1997). A slightly different approach but following the same line of reasoning has been adopted by the DESSAC project (see Section 3.3.1).

Secondly the modern farm business is under pressure to reduce costs, both fixed and variable. A rough idea of the quantity of fertiliser required by a crop at any given time is
no longer acceptable in the light of growing input costs. Modern farmers are very interested in the ideas behind precision farming and are also very aware of the savings that refinements in the calculation of input needs can theoretically produce. The farmer of the 90's may well have been very happy with the purely algorithmic, probably paper-based approach of the 70's and 80's, but is now willing to try out new technologies if they offer the chance of saving costs and improving the profitability of the farm. This is not to say that all table-based and rule-of-thumb-based decision support should be abandoned in favour of the computer approach; the strengths and weaknesses of both in solving any given problem should always be considered before selecting one in favour of the other.

4.2.5 Confidence in results/training

Validation is one of the more difficult problems for the developers of agricultural decision support systems. It is very easy for a piece of software to lose the confidence of users because at times it produces 'silly' answers. Yet it is very hard to produce a system that will not, in certain circumstances, give slightly strange results, either because the model is being pushed beyond its limits or because the combination of circumstances experienced by the grower has not been incorporated into the system's design. The irony is that the support system which gave one bizarre answer and lost credibility may have been capable of improving performance in most other cases. It can operate the other way round as well; the system which in its first year saves the user money will be trusted for the next two or three years even if its performance doesn't merit it.

A slightly different problem concerns the scientists' perception of what constitutes a useful model. Potentially useful models can sit waiting in the wings because those responsible for them feel that they are not yet good enough for public use. While this makes good sense scientifically it deprives the industry of information which, while not perfect, may be better than that currently being employed. When questioned about the accuracy of decision support tools, many farmers and consultants said that they would be happy to use something that wasn't perfect as long as they were given some idea of the degree of accuracy to expect (Parker, 1994). Scientists often forget that farmers and consultants are accustomed to working with a high degree of uncertainty and to adjusting
their decision-making accordingly. If given sufficient information many farmers or farmer/consultant teams will happily trial the system in a part of the farm in the same way that the potential of new crops and varieties are tested every year (Brittain, 1997).

It is the author's belief that while everything should be done to validate the software prior to its release, the only real solution to this problem is the combined communication with, and education of, the end user over a fairly long period. Farmers and consultants alike have to be made aware of the potential of these systems and also of their limitations. As Lorgeou & Waksman state:

>'the public does not always appreciate the possibilities nor the limits of such a tool' (Lorgeou & Waksman, 1997, p.346)

The TIM project\(^ {16} \) (Section 3.6) has gone some way towards this end by conducting a series of awareness sessions for growers in the fruit and brassica sectors of the horticultural industry. The success of these sessions suggests that the industry wants to participate in such a dialog. The availability of training may also be a deciding factor in whether the users take up a piece of software (Levallois, 1992).

The author's experience suggests that glossy hype, which seems to accompany most mainstream commercial software products, will only alienate the people who have most to gain from agricultural DSS. Spelling out the areas in which a DSS performs well and the areas in which it is less reliable makes good sense in the agricultural context. An additional advantage of increasing communication links is that users can be encouraged to provide feedback on the ways in which the model or rule base within a DSS falls short of reality. This serves to facilitate the validation and incremental improvement process and may add to understanding of the underlying biological processes. The size of the UK crop production industry is insufficient for anyone to make a fortune out of developing DSS for its use, the main reason for their development has therefore to be part of a centrally funded technology transfer paradigm. If DSS are seen primarily as tools to

\(^{16}\) (MAFF commission HH9913T)
distribute knowledge then disseminating an understanding of their capabilities and encouraging a free flow of information between user and developer can be seen as useful activities.

### 4.2.6 Support

The responsibility of the developer to the user does not end at the point at which software is exchanged for cash. All modern commercial software houses provide some form of user support, often in the form of telephone help desks. Unfortunately the stereotypical developer involved in agricultural decision support system production is often unaware of these added costs and consequently unable to fund or provide the support needed. This causes great frustration among users and may result in the software being abandoned. Software houses may be uninterested in managing agricultural DSS for the very reason that they know how much support they will have to provide (Horne, 1992). Good technical assistance was listed by designers as one of the tips for success in a survey by Claustriax (Claustriax, 1992) and is also listed by CDER (CDER, 1992) as one of the three main services a good software developer should provide, together with training and maintenance.

### 4.2.7 Choice of user

A further problem that decision support systems in crop production face is the perception, real or otherwise, that they are being introduced to take the place of the consultant or adviser. This fear is expressed not only by the consultants (who are naturally wary of any threat to their livelihoods, particularly in countries where extension services have been taken out of the public sector) but also by farmers themselves (Parker et al., 1994a). To avoid making mistakes and targeting the wrong user group, as would be the case if DSS were designed exclusively for farmers and growers, it is important that the potential users of a system and the role of these users is identified very early in design (Hehnen et al., 1986). The difficulty of separating out the roles of farmer and consultants in decision-making is illustrated in Section 4.2.8.
Decision-making on the farm, as every one concerned is aware, is an increasingly nerve-racking business; wrong decisions can mean the loss of thousands of pounds in crop value or in unnecessary treatments, and in extreme cases they can result in bankruptcy. This may induce the high level of stress and uncertainty which has no doubt contributed to the highest suicide rate of any industry in the UK, as discussed in Section 1.2. Consultants serve a secondary but equally important role on many farms by providing psychological support, i.e. someone with whom the burden of decision-making can be shared. There is often a degree of loyalty expressed to the adviser over and beyond any perceived value they may have in terms of crop production. A DSS, however sophisticated, cannot, and should not, be used to take the place of the crop consultant. Their primary function in the relationship should be to facilitate and support the consultation process.

4.2.8 Tailoring of systems

Separating the roles that farmers and consultants take in a decision-making process is not an easy task as the survey described in Section 3.5 suggests. While many consultants were responsible for identifying the best spray dates, farmers would make the final decision about the most practical date. A considerable amount of communication between these parties takes place each year, planning, negotiating, and adjusting activities according to changing needs. A DSS should support this process by providing a common platform around which discussions take place and which both parties can use. The need to support this type of communication has been stressed by several authors including Hansen (Hansen, 1992) An obvious requirement is therefore placed on the developer to design with both levels of expertise in mind, either to produce two types of interface to the same system or to hide complexity in a way which expert users will not find irritating.

4.2.9 User interface design

The ease of use of the software, its presence or absence, has been frequently cited as a key reason for the failure of a DSS (Cox, 1996; Reisman, 1996; Sankar et al., 1995; Cole, 1995), and as a definite component of its success (Scheepens, 1992). There is no doubt that the user interface design is of major importance; Pitty for instance found that 80% of
design effort was concerned with the user interface design structure and communications functions (Pitty and Reeves, 1995). Good interface design by itself however will not determine success; indeed some systems considered quite unfriendly may gain users if the functionality they provide is sufficiently relevant (Alter, 1981).

A taxonomy provided by Keil et al. (1995) suggests that usefulness and ease of use are equally important. Software which is neither useful nor easy to use is a 'reject' and will not be adopted; software which is useful but not friendly is a 'power tool' and may be used by a small sub-set of potential users 'because the functionality of the tool outweighs its ease of use'; and software which is friendly but not useful is a 'toy', played with for a little while but soon losing appeal. A really successful tool, they conclude, a 'super tool', to be adopted by a wide range of users has to be both usable and useful (see Figure 4.1).

![Figure 4.1: Usefulness & Ease of Use (from Keil et al, 1995)](image)

**4.2.10 Time commitment**

System response time and the time it takes the user to get at the data they need has also been a limiting factor in uptake and not only in the crop production context. Medical systems which pride themselves on only taking five minutes to use have been ignored by doctors as being too slow who otherwise feel their functionality is good. As De Dombal suggests, if a system taking five minutes has to be run 15 - 20 times in a day then that's 1.5 hours time is spent in a non-central activity, which is naturally unacceptable (De Dombal, 1993). Time is critical to crop producers too, particularly during peak times of
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the season; as one grower pointed out 'I've got ten minutes in the farm office to find out what I need to know, if it can't tell me in that time I'm not interested.' (Parker, 1994)

4.2.11 Updating

Constant updating and looking for new uses for functionality are major reasons listed by software designers (Claustriax, 1992) for the success of computer programs. DSS must be capable of adaptation to meet changing needs in the same way that farmers and their consultants are constantly having to do. New crops and varieties and new chemicals appear each year as do new methods for tackling problems and new system software designs. System developers have to be prepared to keep up with these changes or risk losing their customers. For example, DSS which serve a strongly educational role may become unused as farmers become familiar with the concepts and no longer need the support the tool provides.

4.3 USER-CENTRED DESIGN AND TASK FIT AS METHODS FOR ADDRESSING THESE PROBLEMS

4.3.1 Applicability of user-centred design to the uptake problem

It is unlikely that any of the individual factors listed above, if addressed in a more appropriate fashion, would alone result in the creation of a useful and usable decision support system. It is more probable that a more wholesale change of approach is required, before an improvement in uptake is seen. A user-centred design approach, as described in Section 2.3.3, could be the answer. The benefits of this technique include:

1. access to more accurate information about the tasks and problems that users face and must perform or solve;

2. the opportunity to explore alternative design decisions and select interface approaches and designs based on what works best with the users; and

3. a sense of 'ownership' and a feeling of investment in the system for the users.
If a user-centred design approach had been adopted from the beginning of the development of DSS for agriculture most of the problems listed above may not have occurred or would have been lessened.

For example, more knowledge about the tasks and problems that users face and about the environment in which they operate would have prevented the development of systems for which technology did not exist and for non-computer-literate users. It would have reduced the probability of systems being developed which failed to support the task needs of the user, including the need for swift answers to problems at peak times and the need for regular updating. An understanding of the availability of weather data and the time taken in sampling would have stopped the publication of systems requiring a high degree of additional sampling effort or scarce meteorological data. An appreciation of the relationship between farm-based tasks and of the problems farmers and consultants face in communicating between non-standard systems would have prompted the development of industry standards a good deal sooner than has been the case. A truly user-centred approach should also have identified the 'after-sales' requirements of DSS users including the need for help and support.

The opportunity to explore alternative design decisions with users would almost certainly have resulted in fewer failures relating to interface design. This type of iterative design would have enabled the developers to tailor their systems more closely to the requirements of their chosen user group. It is also true that, in those situations where the wrong type of user was made the focus of design, early testing would have revealed the problem. In the fund-restricted environment of agricultural system design, early detection is extremely important if corrective action is to be achieved within the project life span.

Involvement of users throughout the life span of DSS development would have improved confidence in the system. In addition to the sense of ownership suggested above, a user-centred design approach can also, as a by-product, make training needs apparent. The iterative process permits a two-way flow of information, from the developers – keen to
explain the functionality of the system and the limitations of the models, and from the users, keen to explain their needs and to request additional functions.

4.3.2 Advantages of user-centred design methods for agricultural DSS

What evidence exists to support the claim that a user-centred design approach will result in a more successful DSS? Examples are hard to find in the literature, mostly because few successes exist but also because the focus of the description is usually on the technical accomplishments of the system and not the user aspects. Some systems do however stand out as 'successful' in that they claim to have a large percentage of active users within their crop development domains. Some of these are described below.

Integrated Farm Management System

The first tool is a Danish development called the Integrated Farm Management System (IFMS). The system was developed by the Danish agricultural advisory service in response to conclusions drawn from an earlier project. The main conclusions were:

- The user interface to the system must be the same for the farmer and the consultant if consultants are to be responsible for the introduction and support of the system
- The provision of data should be integrated with the provision of advice and technical information
- To succeed the system needs the support of local users
- Integration of system components are required to create a really useful system for farmers
- Telephone links to remote programs are not appropriate for production management and accounting systems.

As its name, and the requirements listed above suggest, the Integrated Farm Management System is not a single decision support system. It is instead a suite of integrated systems that provide whole farm support covering crop, pig or cattle production, buildings and
machinery and financial management. There are 25 programs altogether, grouped within modules for economic and sector management.

The system development process can be labelled 'user-centred' as its authors claim that it was developed with 'the highest degree of user influence' (Pedersen et al, 1997 pp. 483), although the exact nature of the design methodology is hard to judge from the available literature. The IFMS was designed to cover the needs of the two main user's groups: farmers and consultants, even though their requirements differed in some aspects. Farmers requested easy to use programs and consultants required a high level of efficiency.

A measure of the systems success is its use by 6,000 Danish farmers and 1,000 consultants as reported in 1997 (op cit.).

**AgResearch Software**

Another suite of systems which appears to have been well received by the agricultural community are produced by the AgResearch Software in Whatawhata, New Zealand. These packages (called STOCKPOL, TOPFLITE, BOVISION & OUTLOOK) are primarily targeted at New Zealand's pastoral farmers farming sheep, beef, deer, and Dairy. Although surveys contributing to this thesis have been unsuccessful in tracking down figures, the systems producers claim that increasing numbers of consultants and farmers are using the software (Woodwards, 1995). Woodwards ascribes the success of these systems to the development method they employ.

"Our method has been to ask what do farmers (or consultants) want? Then we make use of simple dynamical models and produce a prototype. This goes through several iterations, where a "user group" consisting of the potential clients take away the prototypes ("beta versions") for a couple of months, then come back together and discuss their experience, what worked well, what was a good idea, what was lacking, gripes, etc. The software is modified and another prototype is trialled. So our DSS is very much tailored to the clients rather than scientists. Actually scientists have to stay in the background. I think this is why we have been fairly successful in getting farmers to actually buy and use the software. The software is also effectively promoted by word of mouth from farmer to farmer."

(op cit.)
Even though the author does not speak in terms of user-centred design, the description of an iterative process that involves the user throughout development can clearly be identified as such.

**Orchard 2000**

Orchard 2000 is a decision support system for orchard managers and has also been developed in New Zealand. Like the UK-based DESSAC project described in Chapter 3, Orchard 2000 is really the label for a framework that can accommodate an expanding group of decision support systems. The framework makes it possible for the DSS to communicate with one another, make use of common databases, and present a common interface to the user. Its aim, like most DSS in this domain is to

> "enable communication between growers, consultants, scientists, and industry representatives, and is a system for delivering new research knowledge to orchard industries" (Laurenson & Cross, 1997, pp 241).

The development method was remarkably similar to the type of approach suggested by the DSDM approach (Section 2.3.4). Initial development was the result of the work of a small team of people, including a small group of innovative users (op cit. p 243). As the iterative process continued the project was exposed to a progressively wider group of potential users. Ideas not well received were cancelled or postponed, user groups were specified and the costs, liabilities likely to result from the publication of the software were identified. In addition to the usability benefits brought about by this approach the feasibility tests identified further sources of funding for development, support and maintenance.

To date Orchard 2000 has around 120 users, just under half of whom are apple producers. This is not a huge percentage of the potential market in terms of individual growers (there are approximately 1300 apple growers, 1000 grape growers, and 3000 kiwifruit growers in New Zealand (Laurenson, 1999)). It does however make a sizeable impact on the apple industry, which are its primary target, for the following reasons. The user list contains two of the largest apple producers in New Zealand and therefore the system impacts on a higher percentage of the actual crop than the numbers imply. The list also
contains a large number of consultants, including three agrochemical retailers in the principal apple growing regions of New Zealand (Hawkes Bay and Nelson), who routinely pass information from the software on to their clients. Finally, another group of growers use the information produced by the system, even though they do not own it, via bureau services. For example one company faxes weather risk information to around 120 individual growers, and a group of 30 or so growers in Central Otago receive daily risk faxes from another company (op cit.). The system is also being used in Australia. Ten systems had been sold in that country by the end of 1998, including at least one to a company providing a bureau service to client growers (op cit.).

**Integrated Grain Store Manager**

The final example of a successful agricultural decision support system was developed in the UK by Imperial College and is called the Integrated Grain Store Manager. The system is designed to aid farmers and store keepers in the control of grain store pests. It incorporates a large encyclopaedic knowledge base and also a number of models for the prediction of insect population development under different control options. The program is also designed to encourage good record keeping and therefore provide some accountability of actions.

The importance of a user-centred design approach to the systems developed by the Imperial College team is highlighted in `Decision Tools for Pest Management' (Norton & Mumford, 1993). In brief, the team employ workshops throughout the design lifecycle with key stakeholders. In the text there are several chapters (particularly Ch3, Ch4, and Ch 13) which specify the means by which requirements for decision systems and databases are captured, all based on the workshop approach.

The success of their approach is highlighted by the wide use of the Integrated Grain Store Manager. It was considered useful enough to recently be distributed to all clients of a leading chemical manufacturer.
Summary

As these three examples show there is some evidence to support the advantages of a user-centred design approach to the development of agricultural decision support tools. Unfortunately there are too few successful systems in the industry to be able to make a stronger case. It is true to say however that the research carried out in support of this thesis has, to date, not identified a successful system which has not adopted some form of user-centred design.

4.4 DISCUSSION

This chapter has demonstrated that although there exists considerable potential for DSS in crop production (as discussed in Chapter 1), and many systems have been developed, very few are in widespread use. A range of possible explanations for this phenomenon have been discussed, namely:

- Computer ownership and use on farms
- Usefulness of models
- Data requirements
- Integration between systems
- Confidence in results/training
- Support
- Choice of user
- Tailoring of systems
- User interface design
- Time commitment
- Updating
It has been suggested that, while individually and in groups, these issues have undoubtedly been at the heart of previous DSS failures it is to a change in approach that developers should look for improvements in system uptake. It is postulated that a user-centred design approach would, if adopted by DSS development teams in the past, have resulted in a much lower failure rate. The benefits ascribed to the approach may well have prevented any of the aforementioned issues from emerging, or at least have reduced their impact to manageable proportions.

In an attempt to support the hypothesis that a user-centred design approach to agricultural DSS design would lead to a greater degree of success, the literature was examined for examples of successful systems. Only three such examples were identified. In each case the developers reported a design methodology which, while not labelled as such, was clearly user-centred. No counter examples have yet been found.

In conclusion, it would seem that the key to avoiding a repetition of the failures of the past might be to adopt a design methodology centred on the user. As has previously been suggested, DSS developers are not normally specialised IT people and rarely have any experience of user interaction. In order for these individuals to adopt a user-centred approach they require some guidance in the form of a structured method. The general approach and benefits of a user-centred design methodology are described in Section 2.3.3. That chapter concludes however that there is no commercially packaged or public domain method that is specific to DSS. The next chapter will describe a methodology that could potentially bridge the gap.
5.0 USER-CENTRED DESIGN METHOD FOR CROP PRODUCTION DSS

The previous Chapter argued that the most important contribution to the development of successful decision support systems, i.e. those the agricultural industry would be prepared to buy and use, would be the adoption of a user-centred design method. This Chapter examines the requirements for such a method and proposes a practical solution.

It has been suggested that one of the main factors leading to the poor uptake of previous agricultural DSS to date has been the failure of the developers to adopt methods which pay close attention to the user, their needs and requirements, and to the environment in which they operate. It has also been noted that, on the whole, the developers of agricultural DSS are not DSS specialists and frequently do not have access to the skills and experience of commercial software developers. What is needed, therefore, to improve the usability of these systems is a user-centred design method providing structured support during the design process. In Chapter 2 it was observed that many existing 'soft' methods are limited in their applicability because they do not take account of the practical limitations under which software designers work. Developers cannot afford to take the time which many of these methods require. In order to begin specifying a practical solution to the specific problem raised by the development of agricultural DSS it is important to identify the limitations placed on the developers in this environment.

5.1 THE AGRICULTURAL DSS DEVELOPMENT ENVIRONMENT

5.1.1 Software development

The primary developer of an agricultural DSS is rarely a computer specialist. In most cases, the drive to produce a DSS has originated with the biologist responsible for the initial modelling. In early UK developments this person, someone on their team, or a hired programmer will have produced the system. Almost invariably it will have been an adaptation of a program originally used to explore the science and created with extra
funds secured to deliver the science to the industry. More recently (in the last two or
three years) the need to act in a more commercially-oriented fashion has brought IT
departments within research institutes into the development process. In these cases, the
biologist secures funding to create the DSS and uses part of the funds to pay the IT team
to build a system around the model.

Contact with the agricultural industry during the development of the software has
traditionally been limited. In some cases the developer has not felt it necessary to
communicate with users until the system is ready for release. In addition, the extent to
which biologists are in touch with the needs of the industry varies tremendously. Some
biologists work very closely with farmers, growers and consultants and as a result of
perceived need; others operate very much at the pure science level and have little if
anything to do with users. The introduction of the IT departments has done little to
improve this situation. Historically research institute IT personnel have been responsible
for internal computing and communications requirements and have very few dealings
with the industry.

The commercial experience of the IT teams now involved in the process is still very
limited. Most of them have been employed within a research environment, as part of a
service group, for all of their working lives. There is little knowledge or familiarity with
the practical use of formal software-development methods.

5.1.2 Funding environment

Nearly all DSS developed for UK crop production have been created within an extremely
limited budget. Funding agencies have been reluctant to invest large sums in DSS for
several reasons:

- They do not have large sums.

The Ministry of Agriculture, Fisheries and Food is one of the largest funding
agencies. It has a budget of 142 million pounds for the period 1998-1999 (DTI,
1998) compared, for example, with the budget of over 239 million (for the same
period excluding OST and Launch-Aid budgets) available to the Department of
Chapter 5

Trade and Industry. The levy bodies - Home Grown Cereals Authority (HGCA), Horticultural Development Council (HDC) and the Apple and Pear Research Council (APRC) - raise funds directly from the industry and are closely scrutinised for the value of every pound that they spend.

- The technology does not yet have demonstrable benefits

Funding agencies were initially keen to exploit the possibilities of the DSS as a technology transfer device. The lack of observable success is believed by many to have made them much more reluctant to invest.

- They do not understand software

MAFF and the Levy Bodies have a remit to fund research projects, pure and near market. The mechanisms by which funds are sought, and the scale against which success is measured, are all based on a traditional research model. This model has not been very tolerant of software development projects (although recent moves have improved matters, see Chapter 7) which operate on very different principles. Software projects do not result in publications, the primary measurement of success for academic research. They require funding for support and development after the end of the initial project, completely contrary to the short-term contract culture of the research environment. Within this traditional model of research DSS-based projects therefore appear to be very poor value for money when compared to a more traditional research proposal.

5.1.3 Market restrictions

The market for crop production DSS is restricted in two ways: size, and potential for revenue. As levy payers, many farmers and growers feel that they have already paid for the developments of software funded by the levy bodies, and are reluctant to pay again. If levy bodies deliver the software free, however, no funds are generated to pay for help-lines or further development. Furthermore, the value of DSS has yet to be established in
most user's minds and many are reluctant to pay a realistic market price for software for which they cannot easily see an immediate cost benefit.

The size of the market for any DSS in the UK is extremely small. It cannot realistically generate sufficient income to support and maintain individual DSS, even if the original costs are met by a funding agency. As an extreme example, the majority of carrots grown in the UK are produced by less than a dozen enterprises. The value of the crop is high\textsuperscript{17} and the impact of a decision support system (e.g. cutting the quantity of chemicals applied) on crop quality or gross margin, can therefore be quite considerable. Generating sufficient income to maintain a DSS from this small and highly competitive, user group would however be very difficult. The overseas market for the systems is also highly restricted. The particular conditions within which simulation models operate reliably generally restrict sales to the UK, as do the levy bodies who naturally want to keep any potential competitive advantages for their levy payers.

5.2 REQUIREMENTS FOR A DEVELOPMENT METHOD

5.2.1 Summary of developers requirements

To summarise, the environment in which crop production DSS are developed is characterised by low and variable funding, poor communication between end user and developer, and limited and variable product development skills. The requirements for a user-centred design method to support the production of agricultural DSS in this environment are therefore:

\textsuperscript{17} the 1997 farmgate price for carrots was £156.64 tonne and average crop per hectare 51.7 tonnes, so an average hectare in 1997 was worth £8098 (MAFF ESG, 1998)
Table 5.1: Requirements for a user-centred agricultural DSS design method

<table>
<thead>
<tr>
<th>Environmental condition</th>
<th>Requirement for method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited and variable product development skills</td>
<td>To be structured, and simple enough to be implemented by non-specialists</td>
</tr>
<tr>
<td></td>
<td>To provide clear guidance on what needs to be accomplished at each stage, and how it might be achieved.</td>
</tr>
<tr>
<td>Poor communication between end user and developer</td>
<td>To specify exactly how users are to be involved in the process.</td>
</tr>
<tr>
<td>Low and variable funding</td>
<td>To be flexible.</td>
</tr>
<tr>
<td></td>
<td>To support a wide variety of project sizes, timescales and funding characteristics.</td>
</tr>
<tr>
<td></td>
<td>To be inexpensive</td>
</tr>
</tbody>
</table>

5.2.2 Summary of additional requirements

In Chapter 2 a wide range of methods were examined and their relative merits discussed. The discussion concluded that no single existing method was suitable for the purpose of guiding the project work described in Chapter 3. The problems identified with the existing methods were that:

- Hard methods are not sufficiently user-centred,
- most soft methods are not sufficiently tied into the design process to be useful,
- with the exception of DSDM all methods are designed for large scale software developments, and finally
- none of the available methods were specific to DSS or information systems.

A method to meet the needs of the developers of crop production DSS has therefore also to be: user-centred, clearly tied into the development process, and be appropriate for decision support systems. The importance of this last point is discussed in detail in the next section.
5.3 TASK ANALYSIS

It has been stated that one of the primary characteristics of a user-centred design approach is the use of task analysis (see Section 2.3.3). In the context of human-based tasks, task analysis is the means by which details of the user’s tasks, and information about the task environment, are collected so that the users’ needs are well understood. Task analysis methods are concerned with formal ways of collecting information, organising and using it as the basis for design decisions, and for ensuring that tasks and functions are appropriately allocated within a new system.

5.3.1 Traditional Task Analysis

A large number of techniques fall under the task analysis heading. Many of them share a common approach to the collection and organisation of information about the task environment. That is, to describe a situation, process or task by breaking it down into smaller and smaller sub-units, for example by a process of ‘hierarchical decomposition’, (Annett et al., 1971) until it is considered to be fully represented.

A number of concepts are commonly employed in task analysis, definitions of which are:

- **Goal**: The highest level of analysis. A goal is a cognitive object and is the target of the activity.
- **Tasks or Operations**: Things that have to be done to achieve the goal
- **Actions**: The lowest level of task or operation which contains no problem solving or element of control.
- **Methods or Plans**: A sequence of tasks or actions
- **Objects**: The focus of actions

18 The term ‘Task Analysis’ will be taken to mean human based tasks for the rest of this document
The most well known method within human factors circles 'Hierarchical Task Analysis' (HTA), for example, takes a 'task' as a basic unit and describes this in terms of a hierarchy of operations and plans. A HTA description starts with the 'goal' as the required state, identifies tasks that have to take place for the goal to be achieved, and describes the operations (the lowest level) that have to be carried out to accomplish a task. 'Plans' specify the conditions under which subtasks need to be carried out.

Task analysis methods are so varied that it is hard to know where to employ them, or to identify those that might be useful within the context of agricultural DSS design. One attempt to provide a useful descriptive framework has been made by Kirwan & Ainsworth (1993) Although they admit that some methods did not fit too tidily into single categories, Table 5.2 provides a summarised version of their ideas.

The history of task analysis is rooted in the manufacturing industries and in machine use at the start of the century e.g. Gilbreth (1911) & Taylor, (1911). In industry today task analysis is employed in a wide variety of ways: for ergonomic and technical design of work systems, layout of machines, software development, management organisation, design of shifts and breaks, human resources management, and for research and career advice (Landau et al, 1998). The majority of approaches (e.g. HTA and its hybrid forms) are concerned mainly with the physical aspect of a task, and the steps that are required to carry it out. These traditional task analysis procedures have made significant contributions towards improving productivity in cases where the major elements of the task are observable. However their usefulness is usually limited to manual procedures and they are considerably less effective in the analysis of cognitive activities. As decision-making is almost entirely a cognitive activity, a traditional task analysis approach is not appropriate for use within a DSS development methodology. It has been suggested that task analysis also suffers from other problems which make them less than useful in this context, i.e. they:

- Depict processes as clean, complete tasks.
- Don't (or can't) capture the complexities of real life.
- Don't accommodate variability within processes well.
- Have no provision for the tacit aspects of processes.
- Become complex, beyond easy understanding fairly quickly, and are therefore mainly appropriate to micro-worlds.

Are usually used to gain a consensus view of the process, not a real view. (Sinclair, 1999)

Table 5.2: Focus of task analysis methods for human tasks, from Kieran and Ainsworth (1993).

<table>
<thead>
<tr>
<th>Focus area</th>
<th>Aim of method</th>
<th>Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task data collection methods</td>
<td>Collecting data on actual or proposed task performance</td>
<td>Activity sampling</td>
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<td>Critical incident technique</td>
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<td>Observation</td>
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<td>Questionnaires</td>
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<td></td>
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<td>Structured interviews</td>
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<td></td>
<td></td>
<td>Verbal protocols</td>
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<tr>
<td>Task description methods</td>
<td>Representing such data in a systematic format</td>
<td>Charting and network techniques</td>
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<td></td>
<td></td>
<td>Decomposition methods</td>
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<td></td>
<td></td>
<td>Hierarchical task analysis</td>
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<td></td>
<td></td>
<td>Link analysis</td>
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<td></td>
<td></td>
<td>Operational sequence diagrams</td>
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<td></td>
<td>Timeline analysis</td>
</tr>
<tr>
<td>Task simulation methods</td>
<td>Creating simulations of the task</td>
<td>Computer modelling and simulation</td>
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<td>Simulators/mock ups</td>
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<td>Table top analysis</td>
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<td></td>
<td>Walk-throughs and Talk-throughs</td>
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<td>Task behaviour assessment methods</td>
<td>Assessing what can go wrong in task performance</td>
<td>Barrier and work safety analysis</td>
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<td>Event trees</td>
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<td>Failure modes and effects analysis</td>
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<td>Fault trees</td>
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<td></td>
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<td>Hazard and operability analysis</td>
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<td>Influence diagrams</td>
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<td></td>
<td></td>
<td>Management oversight risk tree technique</td>
</tr>
<tr>
<td>Task requirements evaluation</td>
<td>Assessing the adequacy of the task</td>
<td>Ergonomics checklists</td>
</tr>
<tr>
<td>methods</td>
<td>environment and existing facilities to carry out the</td>
<td>Interface surveys</td>
</tr>
<tr>
<td></td>
<td>task</td>
<td></td>
</tr>
</tbody>
</table>

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5.3.2 Cognitive Task Analysis

'Cognitive Task Analysis' (CTA) was developed in recognition of the fact that there are mental processes that need to be understood and described, in addition to the physical components of a task, if a system is to be optimally designed. CTA concerns itself with the knowledge that people have, or need to have, in order to complete a task. Its approach is to describe and represent the cognitive elements that underlie decision-making, goal generation, judgements etc. (Militello & Hutton, 1998). There are a number of methods which fall under the CTA heading e.g. TAKD and GOMS. The underlying aim of these methods is to identify the 'mental model' employed by the user in carrying out the task, and to use an understanding of this model to improve the system design (Preece et al., 1994). The majority of the data collection for CTA is through in-depth interviews by CTA specialists with experienced users.

CTA is considered to be 'appropriate for tasks that are cognitively complex (requiring an extensive knowledge base, complex inferences and judgement) and which take place in a complex, dynamic, uncertain, real-time environment' (O'Hare et al., 1998). This description would seem to make it a highly appropriate choice for use in a method for DSS developers. Decision-making in crop production can certainly be described as cognitively complex, requiring the manipulation of many variables, as this quote from Bartlett illustrates:

"The decision-making process of farmers involves a range of factors that are taken into account. Each farmer usually makes choices within the context of the household and is influenced by the households need's and goals as well as by the resources available to the household. These resources include not only land, water, labour etc. but also social resources such as information about agricultural methods or credit and any influence or political power necessary in many areas to successful agricultural production." (Bartlett, 1980)

As Chapter 1 indicated, the chaotic nature of weather, the potential interactions between it and the crop and the myriad things that impact on its growth create a complex, dynamic, and uncertain environment.
Unfortunately, there are a number of reasons why Cognitive Task Analysis is not suitable for use in a crop production DSS methodology. These are examined below under two headings, ‘products of CTA analysis’ and ‘CTA methods’.

5.3.2.1 Problems with the products of CTA analysis

The aims of Cognitive Task Analysis as described above suggest that such an analysis is capable of producing a number of descriptions:

- a description of the knowledge required to carry out the task
- a representation of the mental model used by individuals when carrying out the task
- a description of how the user carries out the task (‘how to’ knowledge)

These aspects are described below.

Declarative knowledge

A description of the problem-related knowledge required to make a decision (declarative knowledge) within the crop production context is not too hard to obtain, as the example shown in Figure 5.1 illustrates.

The data in Figure 5.1 was produced during the DESSAC user requirements phase in an analysis of decision tasks on arable farms. Structured and detailed interviews were used to identify the most critical decision points, the most important decision areas, the relationship between the various parties in the decision process and an understanding of the knowledge required for each sort of decision. Farmers and consultants explained the types of information they used, without much hesitation, and there was a great degree of similarity between individuals.

This type of data is very useful to the DSS designer as it describes the information the system will have to provide to support the decision process. It does not, however, tell the designer anything about how to present the information and unfortunately neither do the standard task analysis nor cognitive task analysis methods.
When to spray

This decision was generally rated as mixed in the survey. Advisers were responsible for providing the optimum date and farmers for scheduling the actual spray date. In addition to the advice from the agronomist the farmer will use the following factors to decide on the date:

- weather (land condition, wind, rain)
- availability of personnel
- urgency of problem
- value of crop
- label specifications

With the exceptions of manufacturer's labels and weather forecasts these factors are all based on 'internal' information i.e. information available in the farm.

The adviser makes the decision on the best spray date based on:

- a yearly plan
- growth stage
- plant resistance
- knowledge of the farms constraints
- chemical recommendations
- weather
- research results

Where the adviser is also responsible for the spraying of chemicals the need to schedule a range of clients also has to be taken into account. The decision is largely based on previous experience and knowledge of the clients needs but where external information is required it is obtained from: chemical data sheets; the 'green book' and published research findings. Parker et al. (1994a)

Figure 5.1: Example of data obtained from DESSAC requirements analysis
Mental models

Obtaining a mental model of a physical system within a traditional industrial context may be possible. It is also possible that the same mental model might be used by a number of people. If this is the case then that model might usefully be identified and employed e.g. as a training aid or as part of a navigation device (in software). Within the context of decision-making in crop production however this approach is not so useful.

A mental model of a crop production decision process is not particularly helpful to the system designer because:

- It will vary considerably between individuals.

A mental model of the decision environment is likely to be different for most users because it is based on different levels of scientific knowledge and on the degree to which factors (cost, environment etc) are considered important. One person may have an accurate perception of the crop development cycle and a good model of pest development, and another may base their decision-making on a model of seasonal tasks handed down from his or her parents.

- It is subject to constant change.

Crop production is a highly complex process and many aspects of it are only partially understood. As new science appears, mental models have to change to accommodate it. The degree to which the new material is accommodated by individuals will also vary.

‘How to’ knowledge

Decision-making does not lend itself to the type of analysis which yields useful ‘how to’ knowledge. As Keren (1992) points out ‘many real-life decisions imply ill-defined problems and multiple, often ambiguous goals’ (Keren, 1992. p 29). In such circumstances there is simply no single correct ‘how to’ and probably as many examples of ‘how to’ as there are decision-makers. Identifying an optimum way of arriving at the best decision solution relies on knowing what the best solution will be, and that, in crop
production, may not always be obvious. For example, a good financial outcome for one field/crop may have negative impact on another more important one, or it may be personally inconvenient to apply the optimum.

Decision-making is rarely the logical process we would like it to be (Stewart, 1994), and identifying 'how to' data from decision-makers may not be a useful exercise. Psychological models of decision-making vary to the degree with which they attribute rationality to human decision-making but it has been shown (e.g. Tversky & Kahneman, 1974) that people are likely to adopt recency and frequency heuristics, rather than reasoning, to decide between options. In a crop production context this is reflected in the behaviour of the farmer who, having suffered badly from a disease in the previous season sprays heavily against it, even though the climatic conditions suggest it will not pose a threat.

Identifying ways in which to support less irrational styles of decision-making may be a useful component of a decision support systems (see Section 4.2). The use of cognitive task analysis techniques to identify an optimum 'how to' for decision-making would seem however to be futile.

### 5.3.2.2 Problems with the CTA method

The requirements for a user-centred design method for agricultural DSS developers included the need to be 'simple enough to be implemented by non-specialists'. Cognitive Task Analysis is usually carried out by experienced people and is not easily transferable to non-specialists. Militello & Hutton add weight to this argument when they state that

> "While a wide range of powerful methods of cognitive task analysis have been developed and applied over the last ten years, few have become accessible to training practitioners and the engineering community designing systems.....all have required considerable time and resources. All have been part of research efforts conducted by scientists as opposed to development of an application by practitioners." (Militello & Hutton, 1998, p619)

The requirement for 'considerable time and resources' makes the CTA approach even more inappropriate in this context.
Diaper and colleagues (Diaper et al, 1998) have also criticised current task analysis techniques for not being useful to system designers. They state that task analysis techniques are not compatible with software engineering methods. In their view, more effort needs to be made to develop methods that can be used by software engineers rather than expecting software engineers to adapt to ergonomics methods.

If traditional and cognitive task analysis methods do not provide the type of detailed information required by the DSS developer, or enable teams to access this information quickly and cheaply, are there any other tools which do?

5.3.3 The 'Question' approach

During the research for the 'GRIME I' project it became apparent that some DSS were not being adopted by potential users because they were not answering 'the right questions'. The models they contained were capable of producing information that the user required but the way the system had been designed prevented the user from accessing that information. (see Section 3.4.5) The observation that system developers needed to pay more attention to the actual questions their users wanted to ask of the system was reinforced by discussions with users in the early part of the DESSAC project.

As discussed in Section 3.4.5 these issues had been identified earlier by Arinze. He was also unhappy with the ability of existing and proposed methodologies to meet the needs of the DSS developer. In support of the question approach he stated that:

"The DSS role ... is oriented towards knowing rather than doing. This does not represent terminological sleight-of-hand, but suggests that DSS outputs are more of an indirect spur to action than the other types of system, and that a complete taxonomy of user solicitations or enquiry types involved in 'knowing' will be key constituents of any proposed formalisms.(Arinze, 1992. p. 250)"
5.4 ARINZE'S USER ENQUIRY MODEL FOR DSS REQUIREMENTS ANALYSIS

5.4.1 Background to the method

In Chapter 2 it was noted that none of the mainstream development methods were appropriate for the creation of DSS. The reasons for the mismatch are well argued in (Arinze, 1989). In this paper Arinze notes that the difference between the two types of program is directly related to the nature of the problems which DSS and other systems address. Mainstream methods are concerned with designing for

‘relatively static, well-defined tasks, with low uncertainty, and slow changing user requirements and data structures.’ (op cit. p166).

They cope less well with decision-based activities which are by their nature uncertain and volatile in terms of their information structures and user requirements. This view is summarised in Table 5.3.

<table>
<thead>
<tr>
<th></th>
<th>Traditional applications</th>
<th>DSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasks</td>
<td>Static, well defined</td>
<td>Volatile, hard to define</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Information structures</td>
<td>Slow changing</td>
<td>Volatile</td>
</tr>
<tr>
<td>User requirements</td>
<td>Slow changing</td>
<td>Volatile</td>
</tr>
</tbody>
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Arinze argues that this makes decision support systems a special case and in need of methodologies tailored to their particular attributes. He is not alone in arguing for a DSS-specific methodology, a number of other authors have also suggested approaches which are more suited to the semi-structured nature of a decision environment (e.g. Keen & Scott Morton, 1978; Sprague & Watson, 1986; Martin, 1982). The main methodological approaches to DSS development were described and critically examined
in a later paper by Arinze (1992). A framework summarising their approaches is reproduced in Figure 5.2.

**Figure 5.2: A framework of methods for DSS requirements analysis (op cit. p249)**

In this framework, the main approaches to development are shown to take place in five phases. In ‘Level one’ systemic and organisational analyses are undertaken with a view...
to uncovering opportunities and constraints in the environment. In 'Level two' decisions are mapped along dimensions, or axes, of structured and managerial activity. This analysis serves to classify key decisions in order to better understand the potential role of the DSS. The identification of key decisions is continued in 'Level three' where each decision is decomposed into its phases of Identification, Design and Choice (Simon, 1960). 'Level four' is defined by Arinze as the point at which the primary methods of data collection are focused. That is, the methods chosen during this phase provide the direction for the detailed data collection that follows. In level five the system is formalised. The outcome of the process is a requirements specification containing a description of the user interface, and of the model and databases required to support the decision process.

In Arinze's view, most of the existing methods provided a very high level view of the problem space and had given very little attention to the most critical level, level four, definition of the data collection method. Without an adequate definition, the data can not easily be translated into a useful form. This problem was encountered towards the end of the requirements analysis phase of the DESSAC project when a wealth of information had been gathered about the decision area. The mass of data was, by itself, only partially useful; it required some structure and direction to make it available for translation into a functional specification.

Apart from his own, the only other method which appeared to offer this type of structure was Martin's Decision Graph technique (Martin, 1982). Arinze, however, dismisses this technique as inadequate for two reasons: it does not cover all facets of potential enquiry such as the time dimension, subjective vs. objective information used, and whether prescriptions for action are sought; and it presupposes a clearly identifiable sequence of decisions in an activity, which clearly is not the case in many decision areas. Research by the author has yet to uncover any other methods of this type or further discussion of Martin vs. Arinze methodologies.
5.4.2 Decision enquiries

Arinze reasons that one of the key information flows in the link between the DSS and the user is the stream of requests from the user and that these should therefore be key determinants of the shape and form of the DSS. He argues that when decision-makers interact with a DSS they will invariably make an enquiry of one of three main types. The three types are labelled: state, action and projection.

**State enquiries**

State enquiries are made when the user is seeking information about the state of the world (or a model of it). Information may be sought about the state of:

- entities (e.g. products, diseases)
- processes (e.g. pest and disease lifecycles, market behaviour)
- attitudes (e.g. buyer attitudes, consumer attitudes)
- policies (e.g. legislation, buyer policies)
- people (e.g. staff, customers, suppliers)

The type of query that may be made about these items may be:

- purely descriptive (e.g. What is the current price of Opus?)
- subjective (personal view e.g. am I making enough profit?)
- temporal (describe when a state occurred e.g. When was the last disease risk period?)
- explanatory (why a situation exists e.g. Why is this crop doing so poorly?)
- normative (what should be in normal run of things e.g. If I do nothing what is my expected yield for this crop)

Simple descriptive statistics, such as frequencies and means are also classed as State enquiries, although the data has already been manipulated.
**Action enquiries**

Action enquiries are requests for a plan of action to achieve a specified end state. This is a reverse ‘what if’ question i.e. instead of what will happen if I do this, a projection enquiry asks how do I get to this pre-specified end-state. An action enquiry might be very specific e.g. ‘How should I plant this field to obtain this specific cropping pattern’ or more general e.g. ‘How do I achieve the best margin given this set of circumstances’. In this type of query, it is the function of the DSS to generate actions in response to the user’s goal setting.

**Projection enquiries**

Projection enquiries are more commonly known as ‘what if’ enquiries. They are requests for an indication of outcome given a set of defined conditions e.g. ‘How much will I lose if I delay the application of this spray for three days?’. This type of enquiry also involves the assignment of probabilities to estimated outcomes, and will require risk and sensitivity analyses to be performed on potential solutions.

The Arinze enquiry model links well to Simon’s Intelligence, Design, Choice process, as illustrated by Figure 5.3.

![Diagram](https://example.com/diagram.png)

**Figure 5.3:** The relation of decision enquiry types to the IDC decision cycle (from Arinze, 1992. p. 253)
Chapter 5

As Figure 5.3 illustrates, State enquiries are primarily used in the intelligence phase of decision-making, as a means of collecting the relevant information.

Identification of State enquiries will therefore indicate the data that the DSS must contain to support the decision process. In other words, defining the full set of important questions concerning the state of the 'world' will automatically define the database requirements for the DSS.

Action and Projection enquiries are used mainly to assist the decision-maker in the process of formulating potential decision solutions. These questions require a model of the 'world' before they can be answered. It is not possible to answer 'what if' and reverse 'what if' type questions without some description of the mechanics of the relationships between the objects in the 'what if' world. A full set of Action and Projection enquiries will therefore describe the types of models the DSS will have to contain to support the decision process.

In the Choice stage in Simon's IDC model the decision-maker selects an option from the choices available. In Arinze's model, it is the Projection enquiry which is most important at this stage, as the user explores the consequences of specific action alternatives.

5.4.3 Evaluation of the user enquiry method

The user enquiry method can be seen as a form of task analysis in that it is concerned with the collection of details about the user's task and in understanding the user's needs. It is a formal means of gathering information about the task, of organising it and using it as the basis for design decisions and it can be used to ensure that tasks and functions are appropriately allocated within the DSS.

Arinze takes a narrower view of his method and places it after the task analysis phase of development (level four of his framework in Figure 5.2). He believes that the method should be used in conjunction with other requirements analysis methods and that before its use the following should have been carried out:

i) organisational and systemic analysis

ii) identification of key decisions, and
iii) analysis of decisions by activity level and structurability.

The aim of his model is to use the three types of enquiry to anticipate the user's enquiries and therefore improve the use of the available investigative tools.

The suggestion would therefore be, to carry out an initial level of analysis before looking specifically at the questions the user needs to ask when making a decision. A simple way of achieving this will be examined in the next section. However the decision enquiry method is potentially more powerful, and more useful within the full design cycle, than Arinze appears to suggest. The identification of key questions provides a very neat route into a functional specification and into iterative testing and evaluation. The data requirements of the system are specified by the State enquiries. The models required by the systems are specified by the Action and Projection queries. In addition, each question makes clear what functions the system must provide to support it and therefore gives guidance on what must be available at the user interface. For example, the query 'How much is Chemical X', not only requires that a database of chemicals is maintained within the system but that a means is found of identifying and displaying its price. The query 'What will happen if I delay the spray for three days' not only requires models of plant, chemical and disease interactions but also a means of manipulating the date of spray application, and of viewing the changes in relation to the previous value.

The availability of a comprehensive set of decision enquiries permits developers to test the emerging system against its requirements. Each component, model, database, manipulation function and user interface can be examined against the requirements embodied in the questions. The developers problem is to ensure that the component is capable of answering the question.

5.5 THE USE OF WORKSHOPS

In the last section, an approach for identifying the main components of the decision task was described, an approach which could form the basis of a design method for DSS developers. The approach requires the identification of the main questions the user will ask of the DSS during the decision-making process, but how should this information be
gathered? The requirements defined for the method demand that it has to be suitable for application by non-experts with a limited budget and provide a high degree of user input.

It is proposed that workshops be used to meet this requirement. As defined in Section 2.4, a workshop is ‘a small group of people brought together to work towards a solution to a problem’. In the context of system development, a focus group/workshop consists of between three and twelve people (Krueger, 1994). These people work together over a period to identify if, and how, a decision support system might solve a particular crop production problem. The majority of the participants in the workshop will be user representatives. There will be at least one facilitator, to guide the interaction and prevent it from being side-tracked, and ideally at least one of the IT development team. There is nothing to stop the facilitator and the IT person being the same, or from being part of the IT group.

There are four main reasons why workshops are proposed as the main method of interacting with users. Workshops:

- are cheaper than interviews
- are relatively easy to manage
- have been used successfully in this sector
- are promoted by within a comparable system development method i.e. DSDM

Each of these reasons is discussed below.

5.5.1 Workshops are cheaper than interviews

Other methods of gathering user requirements and of bringing the user into the design process are: interviews, postal surveys, and recruiting users to the design team. All of these methods have merit, and can be adopted within a user-centred design approach, but are not as useful as workshops in this context.

Recruiting users into the design team is possibly the most expensive option, unless they can be persuaded to give their time for nothing. The ‘hostage’ problem is also something
which has to be considered (Damodaran, 1991). It has been noted that users can become so involved in the development that they become developers rather than users and no longer provide useful opinions on usability issues.

Postal surveys are cheap ways of obtaining the views of a large number of people but are only really useful when answers to specific, simple, concrete questions are required. Postal surveys would not be useful for identifying fuzzier issues such as the range of questions users ask or for feedback on a particular user interface design.

Face-to-face interviews are more appropriate than postal surveys or user team members but are also time consuming and costly. The user population in agriculture is, by its very nature, distributed widely across the country. In all of the interview phases of the DESSAC and GRIME projects, it was rare to find subjects closer to one another than 30 miles. This distance means that scheduling more than two or three people into a day is difficult. The act of trying to fit people into a timetable to reduce the travelling effort also absorbs a considerable amount of time. Workshops are much faster and easier to organise, requiring only that a sufficient quantity of people are invited to a pre-specified place to ensure a good discussion.

Workshops are cheaper to run than interviews. There are minimal travelling and staff costs. For example, obtaining the views of eight people may take three days of interviewing, plus another couple of days to organise. A workshop, even if it takes two days to organise will only take half a day to run. Two workshops can be run ‘back to back’ to involve even more people for a similar outlay. As those invited to attend these workshops are usually very interested in participating they rarely request expenses and the travelling costs are therefore minor. The cost of providing refreshments and a buffet lunch are trivial in comparison.

### 5.5.2 Workshops are relatively easy to manage

Workshops are forms of meetings, and most people have attended meetings of one sort or another at some time during their working lives. Most senior personnel have experience in running and managing meetings and the basic skills required to manage a workshop
are therefore present in the research institutes responsible for developing DSS software. Although there are different tasks for the workshop 'facilitator' at different stages if the design process, the provision of a basic structure and guidelines should make it possible for someone used to running meetings to cope easily. It has been the experience of the author that those involved in the agricultural industry are keen to talk about their needs and requirements and very amenable to a range of workshop formats. The main skills required in running these events are those of making sure everyone gets a chance to speak, and keeping to time.

5.5.3 Proven success in this sector

Evidence for the utility of workshops within the agricultural sector can be drawn both from their use within the projects reported in this thesis and from a group working at Imperial College.

The workshop technique was employed within the DESSAC, TIM, and HORIS projects, all in slightly different ways. In the DESSAC project, workshops were initially employed in 1995 as part of the requirements refinement exercise. In this instance a broad range of user requirements had been gathered via face-to-face interviews and the workshops were used to check the validity of the data, and to expand and refine it. As the technical partners had already begun to develop some interface ideas, the workshops were also harnessed as a means of providing early feedback. Three workshops were held over a three-day period, with six, five and nine participants respectively. None of the participants had had any previous experience with the project. There were three parts to the three hour sessions, in the first participants were introduced to the project concept and asked to comment on, rate and add to a list of high level requirements for the full project. The second part focused on the validation of specific requirements for the Winter Wheat Fungicide module. The third and final part was used to show the participants the early screen design ideas and get opinions on their content and use.

The project document, which reported the results of these workshops, concluded that they were

"a useful and productive method of fulfilling project objectives. The participants seemed to feel that the workshops were worthwhile and much positive feedback was received. They
appeared to be confident that their comments had been noted, and would be acted upon, and left with a generally positive view of the DESSAC project." (Campion & Parker, 1996 p31).

The workshops proved to be so useful at providing feedback on the early design ideas that they were used on at least ten subsequent occasions as part of the iterative design process. It is also planned that the workshop format be employed as a means of collating user experience and comment after the two field trial phases (autumn 1999 and 2000).

Success with the method in the DESSAC project led to its incorporation into the proposals for the TIM and HORIS projects. Both of these were short term and relatively low budget exercises. As HORIS was expected to design and produce a piece of commercially available software within 12 months, workshops were considered to be an ideal way of getting the views of a representative sample of the user population at a low cost. Workshops were used at both ‘ends’ of the development period, at the beginning to identify requirements for the information system and pre-release to identify problems in the presentation of the information. As the HORIS system was to be based on an existing software tool from the arable sector, it was also possible to get feedback on user’s perception of the usability of this tool to incorporate into the design. The aim of the initial workshops was therefore twofold, to get detailed information on the type of questions the users wanted to ask of this type of system and the information it therefore needed to contain and to review the information content and format of the existing arable system in the light of its potential use within HORIS.

The final set of workshops were used to showcase the pre-release software and pick up on problems in its information content and layout. The event was very ‘hands on’ with a group discussion at the end to raise points of general concern. Both workshops employed a ‘summarising’ session to bring together the key points made during the day and to ensure that the group agreed a set of priorities for them. This served to reinforce the participants view that we were listening to them and gave the development team an idea of the order in which the problems should be tackled (see Appendix K).

The timing of the workshops in both HORIS and TIM resulted in a much lower attendance rate than was hoped for, most of the groups contained between three and six
people. The high degree of overlap between the views of the individuals represented on the teams however still made it a very useful exercise. The team felt that although the numbers were small, the requirements exercise had managed to capture a representative and useful set of requirements. On the evaluation side, it has been noted by Virzi that

"80% of problems are identified with four or five subjects, additional subjects are less and less likely to reveal new information, the most severe problems are likely to be detected by the first few subjects". (Virzi, 1992 p.457)

This was indeed found to be the case, after the first few subjects the majority of problems were identified and later users simply replicated the findings of the first. This was true across role boundaries (farmer and adviser) for the major problems relating to navigation and appearance. For problems relating to content the distinction between the roles generated different observations, for example consultants were more likely to notice inaccuracies within product, or problem, descriptions. As in the DESSAC workshops user views were sought on the usefulness of the exercise. The response was very positive: of the 21 participants responding, eight rated the organisation 'Good' and 13 'Very Good'. Not all felt they had been able to comment fully on the software however, and their responses suggested that this was due to a shortage of time.

In the TIM project workshops were adopted for a different purpose; there was still an element of requirements elicitation in that the opportunity to extract user opinion on the need for support was taken. The main aim of the exercise was however to educate a range of users on the potential and use of model-based decision support. A workshop approach was adopted in favour of a larger scale and less personal method e.g. lectures at agricultural shows. It was felt that allowing the participants an opportunity to discuss the issues among themselves and to ask questions of the facilitators would be a more productive way of getting the message across.

Although the aim of the event differed in one key respect for the other two projects, the response from the participants was still good. All but one of the 33 workshop participants rated the event as either good, or very good. Comments from the participants also suggested that the workshop had served its purpose in giving the participants more
information on the potential (and limitations) of model-based DSS. The format from this project was considered so useful that it will be used as the basis for a bid for further funding to increase the level of understanding in the industry.

Other groups have also adopted the workshop as a cost effective and useful means of bringing users into the development process. In their book ‘Decision Tools for Pest Management’ Norton & Mumford describe workshops for idea generation as

“a useful way of tapping the imagination and intuition of crop protection specialists when trying to come up with new options for pest management”. (Norton & Mumford, 1993), p49.

They also suggest that their system and decision analysis techniques are best employed ‘in the context of interdiscipliary workshops’.

The Norton and Mumford book devotes a whole chapter to supporting the use of pest management workshops by providing guidelines and advice. Guidance is given on designing a workshop and a checklist of things that need to be considered in the logistics and detailed planning is provided. The only limitation of the book, for the DSS developer, is that is focuses specifically on pest management. While its guidelines and techniques do have a broader applicability it may be hard for the those not familiar with the workshop approach to see past the detail and pick out the essentials.

5.5.4 Workshops promoted within DSDM

The usefulness of the workshop approach is also highlighted by its incorporation in to the DSDM methodology under the heading of JAD, Joint Application Development. JAD is a well-established structured analysis approach to requirements analysis (Dong, 1998). It is intended to promote co-operation, understanding, and teamwork among the various user groups and information systems staff connected with a software development. Workshop participants are all those (or representatives of those) who are affected by the system and those who have the power to make decisions. Much of the direction for a DSDM development is obtained through JAD ‘sessions’, which are forms of workshop.
Each JAD session has a detailed agenda, visual aids, facilitator who moderates the session and a scribe who records the agreements made within the session. A final document containing all the decisions made by the group is generated after each session.

There are five phases in a JAD session:

- **Definition**: defining project purpose, scope, and objectives, identifying JAD team members, setting schedules, etc.

- **Research**: gathering more details about the user requirements, exploring problem domain, considering design issues, etc. Based on the research, an agenda is prepared listing what needs to be decided in the session.

- **Preparation**: preparing everything needed for the session, such as visual aids, working document, flip charts, and overhead transparencies.

- **The Session**: JAD team members define business process, project requirements, etc. Decisions are documented for the final document.

- **The Final Document**: information captured in the session is incorporated into a document.

JAD is used, mainly within the Rapid Applications Development domain, for requirements analysis and is considered a very effective tool. As one satisfied user put it:

‘JAD works, DSDM or not’ (Harrison, 1998).

It is also marketed, by numerous software consultancies and training agencies, as a method for improving the success of the software development process. For example the Bauhaus Consultancy Group states that

“The use of Joint Application Development (JAD) techniques is based upon the observation that poor intra-team communication, incomplete requirements definition and lack of consensus are the primary inhibitors of project success” (Group Bauhaus Consulting, 1998).
5.6 A PRACTICAL APPROACH

5.6.1 Summary of contributions to the approach

To summarise, there is a need for a user-centred design method for the producers of agricultural DSS. To be effective this method has to support the main design phases of planning, design, construction, and maintenance. It has to be cheap, simple, structured and flexible, and appropriate for DSS. Finally, it has to provide enough detail to support the inexperienced developer.

While the use of task analysis has been identified as one of the main characteristics of a user-centred design approach, it is clear that none of the existing methods (e.g. HTA, CTA) is completely appropriate. While providing guidance on appropriate tools to use in a high level analysis, existing task analysis methods simply do not provide any useful information on the ideal structure of a decision support system. The Decision Enquiry method proposed by Arinze however offers a means of identifying the requirements for the practical aspects of the system.

Finally, the workshop approach has been suggested as a cheap and effective means of gathering data and of involving users in the design process.

Bringing task analysis tools, the decision enquiry technique and the workshop approach together, and integrating them with experience from the various projects contributing to this thesis, results in a structured method which meets all of the requirements listed above. The method is described in detail under the general headings of planning, design, development, and construction tasks. While the context of this method is unique, little of the content is original and owes much to established practice and earlier work in human factors and market research (e.g. Kreuger, 1994).

Within each of the tasks listed below there may be a varying number of workshops, and a varying degree of other activity. The minimum activity considered to be useful will be described in Section 5.6.6 where the flexibility of the method is discussed.
While the way the tasks are laid out suggests a waterfall model, this is not the intention. As discussed in Chapter 2, a more flexible approach is required for most real-world problems. The tasks outlined below are seen as being linked according to a Star model approach (see Figure 5.4, repeated from Chapter 2 for convenience) i.e. where development can begin at any stage and may be followed by any other stage. The process of requirements identification and system design are seen as evolutionary.

Figure 5.4: The star life cycle (Hix & Hartson, 1993)

5.6.2 Planning

The main activities in the planning phase of development, as described in Chapter 2, are:

- project selection
- feasibility (problem definition, problem identification)
- analysis of problems
- requirements analysis
- choice of technical options

Of these, the last one, choice of technical options is perhaps the only activity which cannot be completed in a workshop setting, although it can be informed by one.
The topics listed above have been grouped under two main headings for the purpose of this section. These headings reflect a natural division into two phases on information gathering. In the first, the need is to reduce the focus from one in which many projects are potentially feasible and in which no guidance has been obtained from industry, to a clear statement of direction. At the end of this phase, it should be possible to state the decision area on which the development will be based. It should also be possible to support the choice of decision area by reference to stated industry problems and requirements. The second phase begins with a broadly stated decision area e.g. support for fungicide decision-making for winter wheat. On its own, this statement provides no guidance for the development of the system and the aim of the next stage is to define the shape of the DSS.

**Selecting a suitable & feasible DSS project**

Selection of a suitable and feasible project can take a number of forms. It is possible to present users with a choice of potential areas of interest to the developers and to get feedback on which of these would be the most useful to them. This, however is simply a form of ‘the problem looking for a solution’ approach, with a bit more choice for the user, and is not taking the notion of industry-directed development very seriously. A better technique might be:

- brainstorming the areas which cause greatest problems in the sector of interest; with the involvement of user groups
- matching problem areas to available models or expertise
- exploring the possibility of creating new models
- considering the relative costs and benefits of the various options
- agreeing an option which is both of major benefit to the sector and technically and politically feasible.

These tasks can be achieved within one or more workshop sessions, with possibly a few scoping interviews if very little is known about the sector of interest.
**Who should be invited to the feasibility workshop**

One of the aims of a workshop at this point in the project is to gain intelligence on the decision areas that cause the most problems to the sector(s) and in which the addition of more science in the form of a decision support system might most usefully be applied. It is therefore important that representatives of those involved in making decisions are present in the workshop (see Section 5.6.7 for a detailed discussion of sampling and representation within a workshop or other form of information elicitation exercise).

If knowledge of the sector is limited, advice on the type of people to select for the workshop(s) may be sought from someone with wide practical experience e.g. a practising agronomist. If time and resources permit several 'scoping' interviews may be carried out to provide background information. (Scoping interviews are those in which a view of the sector, and the players and processes within it, is obtained. An initial interview is conducted with someone who is perceived to have a good overview of the sector. This interview, which is largely unstructured, may be viewed as a first rough sketch of the topic of interest and one which highlights areas in which more investigation is required. The results of this discussion are used to identify areas and people who might usefully be the subject of further interviews, or of bringing together in a workshop. In this way, knowledge of the area is both broadened and deepened. This type of interviewing method was employed in the first phase of the GRIME project to inform the later structured interviews.)

Depending on the area of interest the range of users involved in the workshop may vary considerably. If an understanding of problem areas, from seed to consumer, is required then representatives from all groups involved in the intermediate stages will have to be involved. In most cases however, it is in a specific portion of the supply chain in which problem identification will be focused (e.g. farmers and advisers).

The other groups which have to be represented within the workshop are those which understand the availability and limitations of the science and the technology which make up the system i.e. biologists and software developers. At this point in the process, the biologist(s) should be chosen for the breadth of their understanding of models and
scientific knowledge in the area and the software developers for their experience in DSS or related applications.

The facilitator of a workshop is an essential figure. This person guides the discussions, summarises debates, and ensures that the aims of the workshop are met and that everyone leaves feeling that they have been heard. Experience suggests several characteristics to look for when selecting this individual:

**Good meeting management skills** i.e. ensuring

- everyone gets a say and that the more vocal members don’t dominate
- that the aims of the meeting are achieved
- good time keeping
- that debate doesn’t drift off onto a tangent or become bogged down on one small area
- that the views of the group are summarised to the satisfaction of all

**The ability to be an interested outsider.**

It is important that the facilitator not be seen to be biased towards one decision area or group, or to be leading the debate or discussion in the direction of their own choosing. The more interest that is shown in the issues and problems presented by workshop members the more they are likely to respond and generate interest of their own.

**Enthusiasm.**

DSS require a considerable input from the industry if they are to be successful. It is essential that enthusiasm for the project be generated at an early stage and maintained throughout. If it is true that enthusiasm is contagious and that successful salespeople always believe in their own products the facilitator must be both an ardent believer in, and enthusiastic about, the utility of DSS.
Chapter 5

Convening the feasibility workshop

It is entirely possible to get reasonable representation at these events by contacting known individuals (although care should be given not to bias results by choosing from a small circle of people known to one another) or by making a public call for support (see DESSAC and HORIS reports in Appendices J & F respectively). However a more cost effective means of obtaining this type of data may be to create a space for discussion within another type of meeting, or gathering, at which key people are already present e.g. Interest group, scientific meeting, industrial conference.

Selecting the time of year to hold the workshop is critical. It is important to check the ‘slack’ times in the sector of interest, or at least to check for the peak times and avoid them. Many field crop farmers, growers and consultants experience a quieter period between November and the end of February, when crops are not growing and the land is too wet to work. Many are accustomed to using this time to attend seminars, shows and conferences and it is therefore the best period to approach them.

It is also important to avoid clashes with shows and events in the sector. This may mean not holding workshops in the same week, in addition to avoiding the same day. People are often reluctant to take two days out of a working week when they may be persuaded to take one.

Content of the feasibility workshop

The workshop should begin with a clear statement of its aims, the tasks to be accomplished and of the time slots allocated to each task. Leaving this information somewhere clearly visible will help to reinforce the focus of the discussions and facilitate timekeeping.

In the next part of the session the main problems encountered by the industry-based participants should be explored. There are many ways this might be achieved and the choice will depend on the area of interest and the existing degree of knowledge about it. One method is to ask individuals to come prepared with a list of their ideas that are then debated and expanded. Another, used within the TIM project involves splitting the group,
into sub-groups containing three or four individuals. Each group is lead through the growing year, and through phases in crop production, and asked to identify the main decisions they have to take at each point (e.g. 'imagine it is spring and the crop is just about to enter growth stage 31, what decisions have to be taken'). Having identified decision areas, the small groups are asked to pick out those which cause particular problems i.e. which are not straightforward and in which mistakes can be costly in terms of time and/or money. The problem areas are gathered and organised on whiteboard or flipchart so the whole group can see them, additional areas may then be added as the whole picture triggers memories. From these topics a choice of problem area can be made.

When trying to make choices among potential project ideas it is important that each is assessed in terms of its cost effectiveness. One method of achieving agreement on the best target for DSS development is to create a grid of rankings based on aspects of interest a) importance to the workshop group, b) degree of time and/or money the system could potentially save the user and c) costs of development (the costs of maintenance are particularly important to include in this calculation, see Section 5.6.5). An additional factor 'political importance' could also be brought to bear where choices get difficult; funding is more likely to be forthcoming for projects which meet stated political agendas (e.g. reduction of pesticide use). Table 5.4 illustrates the type of grid which results from this exercise.

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<thead>
<tr>
<th>Problem area</th>
<th>Importance to group</th>
<th>Time/cost saving</th>
<th>Cost of development</th>
<th>Political interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aphid spray and timing</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Nitrogen application</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Cattle herd management</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

In the example above, the system to support decisions about aphid control is clearly the most important to the group. It is also the most expensive. In this case however, the
need to control the use of pesticides is currently higher on the political agenda at the present time than the need to reduce nitrogen run-off. Funding for this project is therefore more likely to be obtained, and the more expensive but desirable choice, can be supported at least initially.

Having identified one or more target decision areas, the session should end by identifying those who need to be involved in the system development. For each chosen topic the workshop should identify the ‘stakeholders’ i.e. all the groups, and sub groups who will be directly and indirectly affected by the DSS.

**Problem and requirements analysis**

<table>
<thead>
<tr>
<th>Features</th>
<th>Definition</th>
<th>Provides specification of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-tasks</td>
<td>Aspects of the decision which have distinct requirements</td>
<td>System modules or ‘views’</td>
</tr>
<tr>
<td>State enquiries</td>
<td>Questions concerning the state of a system</td>
<td>Information to be included in system (database requirements)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interface facilities for database manipulation and information display</td>
</tr>
<tr>
<td>Action enquiries</td>
<td>Reverse ‘what if’ questions – given that this is the case what should I do?</td>
<td>Model requirements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interface facilities</td>
</tr>
<tr>
<td>Projection enquiries</td>
<td>‘What if’ questions – what will happen if I do this?</td>
<td>Model requirements</td>
</tr>
<tr>
<td>Information sources</td>
<td>What information is currently used to inform the questions, what is harder to obtain/collate than others</td>
<td>‘What if’ interface facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Where information can be obtained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential problem areas for information provision</td>
</tr>
</tbody>
</table>

The first part of the planning task identifies the decision area on which the system is to be based. The next goal is to gain sufficient understanding of the decision, and the context in which it is made, to inform the development of the DSS. It is at this point that the identification of decision enquiries or decision-based questions becomes important. The
goals are: to identify the sub-tasks or stages within the decision process, the questions asked within them and the sources of information currently used to inform the questions (see Figure 5.4). Identification of these features of the decision task is the first step in specifying the structure and form of the DSS. The way in which it achieves this is summarised in Table 5.5 and discussed in more detail in Section 5.6.3.

Workshops are, again, suggested as a cost-effective means of gathering this data. Interviews are an equally useful but more expensive alternative.

Who should be invited to the requirements workshop

As this task begins with a specific idea in mind and an understanding of the groups involved in the decision-making process, the choice of participants is not difficult. A sample of each of the stakeholder group should be included. Guidelines on sample selection and workshop size are the same for all sessions and are discussed in detail in Section 5.6.6. Ideally, this group of workshop participants should be different from those involved in the original set. This enables data gathered from the previous group to be validated and also spreads knowledge of, and a feeling of involvement in, the project a little further in the sector. It also prevents the problem of making a group of users ‘hostages’ to the project (Damodaran, 1991) as described earlier in this chapter.

Convening the requirements workshop

As previously mentioned the time of year is very important if a good sample of potential users is to be included in the design. Having a specific decision area in mind (and therefore target audience) will make it easier to identify, and avoid, clashes with peak periods and industry events.

Content of the requirements workshop

Again all workshops should begin with a clear statement of aims, the tasks to be accomplished and of the time slots allocated to each task. The aim of the session in this case is to identify the sub-tasks, if any within the main decision area e.g. spray planning...
can be divided into 'pre-season planning' and 'within-season planning' tasks with slightly different decision support requirements, as illustrated in Figure 5.5.

<table>
<thead>
<tr>
<th>Main decision task</th>
<th>Fungicide application on winter wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key question</td>
<td>What is the most cost effective spray plan for my purposes?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Questions:</th>
<th>Identification and ordering of chemical requirements at the start of the season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>What is the likely disease risk in this field/block</td>
</tr>
<tr>
<td></td>
<td>What is the most cost effective spray plan</td>
</tr>
<tr>
<td></td>
<td>Which products do I need to order</td>
</tr>
<tr>
<td></td>
<td>When do I need to order and in what quantities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub tasks</th>
<th>Refining a basic spray plan during the season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Is there something about which I need to take action</td>
</tr>
<tr>
<td></td>
<td>Is there, will there be a problem</td>
</tr>
<tr>
<td></td>
<td>What is it and how serious is it</td>
</tr>
<tr>
<td></td>
<td>What do I do about the problem if one exists</td>
</tr>
<tr>
<td></td>
<td>What fungicides will do the job</td>
</tr>
<tr>
<td></td>
<td>Which are the best for me</td>
</tr>
<tr>
<td></td>
<td>What is the best dose/timing for their application</td>
</tr>
</tbody>
</table>

**Figure 5.5: Division of main DESSAC fungicide decision into two subtasks**

Sub-tasks may also be generated by different user groups. In the projects discussed in this thesis the division between the user groups in terms of system functionality were not clear. This may not be the case for other systems. It is possible to imagine a system which contains a core set of functions used by all, and some which have particular relevance for individual groups.

Having identified sub-tasks, the aim of the session is to draw out the questions the user asks in the course of completing them, and the sources of information used to support them. There may be several ways to elicit this information within a workshop session, the following is one suggestion.
Begin with a review of the structure of the decision task, i.e. does it take place at one point in the year or are there several informationally distinct iterations within the decision-making process. Are there other distinct tasks to the decision-making task in which different types of information are employed? Within the DESSAC fungicide decision task, one part of the decision is focused on the field or block and another is based on the view of similar activities across the whole farm. A spray plan may be optimised for the field, then amended slightly to fit in with whole-farm activities e.g. the spray program for adjacent fields.

In a workshop setting each sub-task can be considered in turn and the group asked to brainstorm all questions associated with it. Each question should be visibly recorded on a white board or flip chart to act as a memory aid and trigger for additional questions.

If possible the facilitator should dynamically enter queries into one of the three main areas suggested by Arinze: state, action and projection. This process is likely to identify questions which are really composite and can be broke down into smaller units e.g. 'Is it worth my while spraying' might be broken down into 'how much disease is there', 'how much damage will it do to the crop if left untreated' or 'what are the costs of treatment against the costs of not treating'. The process of examining the questions from a different perspective may also stimulate new lines of thought.

Attention should now be given to the importance of each question to the success of the decision and to the information currently used to support them. Table 5.6 illustrates the types of response gained from this exercise within the DESSAC project.
Table 5.6: Questions and information, from the Action enquiry component of the DESSAC requirements specification document (Parker, 1996b. p.8)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How does spray A compare to spray B?</td>
<td>Dose response curves, Cost</td>
</tr>
<tr>
<td>1-2</td>
<td>Which of these chemicals is the most effective?</td>
<td>Cost of chemical, Tank mix characteristics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Effect of delays on cost and application rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential yield loss from not spraying now</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The lowest dose for effective control, taking into account: Time, GS, Variety, Yield potential -</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Market and market value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disease pressure (Sowing date, Crop canopy structure, Weather (pre), Weather (post), Soil factors (type)</td>
</tr>
<tr>
<td>2-3</td>
<td>Duration of effect (eradicant and protectant) of chemical?</td>
<td>Very little available - needs to be researched from trials data</td>
</tr>
<tr>
<td>2-4</td>
<td>What should I use to reduce resistance of fungal disease to the chemical?</td>
<td>Variety, dose response curves</td>
</tr>
</tbody>
</table>

In the DESSAC example, the questions were given a rating of one, two, three or four by domain experts if they were considered vital, important, useful, or interesting. This technique can easily be applied within a workshop setting. When examining the importance of each question the group can also be asked what information they use, or believe is required, to support it. Valuable insights into the availability and usefulness of information sources can be obtained in this fashion.

From a swift examination of the essential and important questions, and the information associated with them, it should now be possible to get a feel for the shape and feasibility of the DSS. The workshop should end by summarising the important questions the DSS will support and the information it will ideally contain. Final discussions may be held to identify sources and potential problems to be encountered in gathering and delivering the necessary information.
If information, which has been rated as vital to a vital question, is also considered currently impossible to obtain, the feasibility and focus of the project may have to be re-examined.

The data gathered from this exercise or group of exercises should be written up and distributed to all developers as a user requirements reference document.

5.6.3 Design

The input to this stage is a set of sub-tasks, ranked questions and information sources. The task now is to translate these into a system specification. A system specification is defined as a ‘document that clarifies a client’s requirements in an unambiguous form by re-specifying the requirements and distinguishing between system functions and the constraints the system developer has to work under’ (Preece et al., 1994).

The requirements document should provide sufficient detail to define:

- The models required within the system
- The database contents and structure
- Other information requirements
- The interface facilities required to interact with the models and database

The way in which it does this is illustrated in Table 5.6 in the previous section.

Model specification

The requirement for the main model is defined by Projection and Action enquiries (‘what if’ and reverse ‘what if’). As Arinze suggests, both of these rely on a model of the underlying system. In the DESSAC project this model was labelled the ‘process model’, as it described the processes underlying the interactions between crop, chemical and weather. The need to support the ‘choice’ stage of the decision process resulted in the development of a second model, the ‘decision model’, for the Wheat Disease Manager DSS in DESSAC. Choice stage questions e.g. ‘which one is best for me’ are present in
both Action and Projection categories. The WDM decision model is designed to identify and rank potential spray plan solutions for a given problem.

A requirement for models may also be indirectly identified from State enquiries, if they are appropriate sources of information that cannot be stored in a database, or easily obtained from another source. An example from the DESSAC project is the Growth Stage Model. Information about the current growth stage of the wheat crop was essential to the functioning of the process model. Growth stage, is however not an easy thing to identify without training, and could not be provided reliably by many of the intended users of the system. A model was therefore developed to generate the growth stage information.

The decision about which models should be developed, or adopted, should be taken by those concerned with the modelling aspects of the project, bearing in mind the need to be able to answer the Action and Projection questions.

*Database and other information source specification*

Database contents and structure are informed by State enquiries and the additional knowledge about current information usage.

Most modern databases are developed according to an object oriented approach, which requires the developer to identify the main objects within a system and their attributes. An object might be a farm and its attributes fields, crops, varieties, planting dates, spray plans, and so on. The information associated with the State enquiries and the State enquiries themselves should make it possible to identify the main objects and attributes and therefore develop an initial database specification.

From the example provided in Table 5.7 it is possible to see that there is a requirement for databases containing information about the field, its history and the spray plans associated with it, for financial information associated with the spray operation and also for information about varieties in general.
Table 5.7: Example of data obtained from an examination of State Enquiries

<table>
<thead>
<tr>
<th>Rank</th>
<th>State enquiries</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Do I need to spray against eyespot?</td>
<td>It is present? Growth Stage?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crop health/condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is anything else being treated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Action at 30/31 (previous action)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Previous cropping</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level in field. Drilling date</td>
</tr>
<tr>
<td>1-2</td>
<td>Do I need to spray for septoria, yellow rust, or mildew?</td>
<td>Disease presence (easily found and spreading for Mildew and easily found for Rust)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Growth stage, leaf emergence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trials results. Variety risk rating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Current and recent past weather conditions - particularly rainfall</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Past weather conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Past crop info (spray, sheet comments)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Action at 30/31, Drilling date</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean of last three years</td>
</tr>
<tr>
<td></td>
<td>Should I spray to control diseases of the ear?</td>
<td>Growth Stage</td>
</tr>
<tr>
<td></td>
<td>(Fusarium, sooty moulds, black-point, ergot)</td>
<td>Variety. Weather</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost of spray</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Margin over spray cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Date of drilling.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Temp in April &amp; May</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Growth stage model ideally)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is it home saved or certified</td>
</tr>
<tr>
<td></td>
<td>What are the financial implications of this decision?</td>
<td>NIAB ratings, local trials, local risks</td>
</tr>
<tr>
<td>2</td>
<td>When will leaf three emerge? i.e. do I need to spray against septoria?</td>
<td>Photos, descriptions</td>
</tr>
<tr>
<td>2</td>
<td>Should I treat the seed?</td>
<td>User records</td>
</tr>
<tr>
<td>2</td>
<td>What diseases are my varieties susceptible to?</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>What is this disease?</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>What problems have I had before, what did I do about them?</td>
<td></td>
</tr>
</tbody>
</table>
Additional discussions with domain experts are likely to be required to amend the initial specification as the way in which the attributes are distributed among the objects may not be obvious to someone outside the process. During a validation requirements workshop for DESSAC the following distribution of attributes among two main farm data ‘objects’ were thus defined:

**Crop data:**

Generally above ground information and data about this year only e.g. variety, cultivations, drill date, applications (dose, active ingredient & date of application), spray information (product, quantity, problem, field inspection sheet, recommendation sheet, wind speed and direction and all legal statements).

**Field data:**

Generally below ground and historical data e.g. field name/id, size, height above sea level, environment of field, warm or cold aspect, fertiliser data, pH, NPK levels, soil analysis results, drainage maps, yield maps, crop, cultivations, varieties. (from (Campion & Parker, 1996 p.20)

Some information requirements are not optimally met by databases or models. In the example in Table 5.7 one of the questions ‘what is this disease’ was most usually answered by flicking through identification guides and colour pictures in books. The provision of this type of information was achieved in the DESSAC and HORIS projects by giving the user access to a form of on-line book. In the DESSAC example this is browser supported and in HORIS delivered within a publishing system called FolioViews™. Both of these use hyper-link navigation.

**Interface facilities**

To generate the lists of facilities required within the DSS it is necessary to ask how each question could be answered effectively by a DSS. That is, what tools would be required to support the user in asking and answering each question. To use an example from
Table 5.7, the question ‘Do I need to spray against eyespot?’ requires the following information to be answered effectively:

- Is the disease present in the crop?
- Level of disease in field
- Current growth Stage
- Crop health/condition
- Is anything else being treated (sprayer going through anyway)
- Action at growth stage 30/31 (previous action taken)
- Previous cropping history
- Drilling date

The answer to the question could be provided in several ways

a) by enabling the user to bring all of the relevant information together on one screen or

b) by using a process model to analyse all of the relevant data and generate a response.

In either case there is a requirement for facilities to support the storage, access and manipulation of the data. In both there is a requirement to display the information together on the screen, the first to use it for decision-making, in the second to check the inputs to the model. In the second there is the additional requirement to display an answer to the question.

This is a fairly time consuming process and many of the interface facilities will be identified several times over. Three types of facility are likely to emerge from the process, those relating to database manipulation; those relating to model use and those which manipulate data from either or both of these sources in some fashion.

Table 5.8 from the DESSAC function specification document provides an illustration of these three facility types.
Facilities one to three relate directly to database and information source access, four to six are model interactions and seven to nine take the output of models and database and order and display them in a particular fashion.

Table 5.8: facilities to support within-season spray planning decisions

<table>
<thead>
<tr>
<th>Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Ability to retrieve, store and manipulate existing spray plans</td>
</tr>
<tr>
<td>2 Ability to transfer the spray plan details to other external modules e.g. for ordering materials, producing spray operator workplans.</td>
</tr>
<tr>
<td>3 Ability to call up basic diagnostic, disease and scientific information - see last section.</td>
</tr>
<tr>
<td>4 Estimation of potential disease threat</td>
</tr>
<tr>
<td>5 Estimation of optimal (most cost effective) spray timing and rate</td>
</tr>
<tr>
<td>6 Estimation of growth stage</td>
</tr>
<tr>
<td>7 Ranking of most effective active ingredients</td>
</tr>
<tr>
<td>8 Ranking of products according to pre-selected criteria i.e. cost, percentage of active.</td>
</tr>
<tr>
<td>9 Ability to compare and contrast the outcome of potential situations - see next section.</td>
</tr>
</tbody>
</table>

Again the results of the specification process should be recorded and distributed as reference to project personnel.

System design

This is the part of the software development cycle that is often seen as the most rewarding and creative. The initial system specification can usually be met by a variety of database and interface designs. The design solution chosen may not be the most optimum, and re-design is nearly always required in some form after exposure to users. A design solution which follows from the system specification, and which in turn is generated from the user requirements is likely to require fewer and more minor changes than one which emerges straight from the creativity of the developer.
System design is very specific to a project and little can be said about it in this context. The next chapter will discuss interface design for crop-based DSS in some detail but this section will conclude with several general suggestions.

When organising the facilities within the user interface, attention should be paid to the sub-tasks identified within the requirements task. These sub-tasks may suggest different 'views' on the data, or different modules containing their own self contained set of facilities and information, especially if the sub-tasks occur at different points in time.

Recording design solutions against requirements, their justification and subsequent changes, is very important for model, database and interface design. Experience from the DESSAC project suggests that many design reviews may be undertaken in a complex system as new components are developed and new feedback obtained from users. A reference is essential to prevent changes being made which unleash problems previously encountered but not recorded. A design record of this kind will also show clearly what parts of the interface were designed within restrictions imposed by the development tools at the time and not because of a system requirement, thereby making change an easier task.

In the DESSAC Functional Specification Document (which is more of a design record than a functional specification) high level design solutions were recorded against required facilities. Table 5.9 illustrates this the in-season spray planning task facilities.

**Detailed design**

In the detailed design task more detail is added to the design document described in the previous section, ideally after tasks of validation and testing with users (see Section 5.5.5). Detailed design should adhere to agreed standards (e.g. Windows '95 standards, Microsoft, 1995) and any appropriate user interface guidelines (see next chapter).

**5.6.4 Construction**

The design process would not be complete without mention of the construction task but there is really very little to say about it from a user-centred design perspective, apart from
the need to adhere to the specification. If (or when) the design proves impossible to deliver, new designs should always be based on the original specification.

The construction task, as with the design task, should be part of an iterative cycle which incorporates as much user involvement as possible.

<table>
<thead>
<tr>
<th>Facility</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to retrieve, store and manipulate existing spray plans</td>
<td>Links to user’s existing crop management software (CMS)</td>
</tr>
<tr>
<td>Ability to transfer the spray plan details to other external modules</td>
<td>Limited CMS functions within DESSAC Shell</td>
</tr>
<tr>
<td>Ability to call up basic diagnostic, disease and scientific information.</td>
<td>Not possible yet - Version 2?</td>
</tr>
<tr>
<td>Estimation of potential disease threat</td>
<td>WDM encyclopaedia</td>
</tr>
<tr>
<td>Estimation of optimal (most cost effective) spray timing and rate</td>
<td>Process model</td>
</tr>
<tr>
<td>Estimation of growth stage</td>
<td>Process and decision model</td>
</tr>
<tr>
<td>Ranking of most effective active ingredients</td>
<td>Growth stage model within process model</td>
</tr>
<tr>
<td>Ranking of products according to pre-selected criteria i.e. cost, percentage of active.</td>
<td>Optimisation screen</td>
</tr>
<tr>
<td>Ability to compare and contrast the outcome of potential situations.</td>
<td>Yield/Margin display area in Decision views and Optimisation Screen, League Table screen</td>
</tr>
</tbody>
</table>

5.6.5 Validation task - iteration during design

The iterative process of system specification and design should include additional user involvement to validate and ratify the material. Development of early prototypes is a core principle of user-centred design as prototypes are an excellent way of illustrating the aims of the development team. A workshop format is again a useful format for the
validation and checking of requirements and design ideas. Other devices which could be employed at this stage are postal surveys (very useful for checking the wider application of workshop findings) and 'expert evaluations'. The latter are described later in this section.

**Who should be invited to the validation workshop**

The participant profile for the validation workshop is the same as that of the requirements workshop i.e. a sample of each of the stakeholder group should be included. Once again, in an ideal world most of the people within this group should be different from those who participated in the requirements stage, to widen the validation and encourage ownership. In some cases however it might be considered politically advisable to include some of the original team in the validation. For more on the use of 'tame' users see Section 5.6.6.

**Convening the validation workshop**

As per previous workshops.

**Content of the validation workshop**

The aim of a validation workshop at any stage of the design and build process is to gain user feedback on the accuracy and usability of the translation of their requirements. Other important functions of a validation workshop are the identification of additional requirements and the identification of training and help requirements.

Feedback can be obtained on paper specifications, paper prototypes, mock-ups and full prototypes. Paper specifications are the hardest to incorporate into a workshop setting and full prototypes are the easiest, the others form a scale between. Paper specifications, paper prototypes and mock-ups are normally used in the early stages of design, fully functional prototypes appear towards the end of this stage and into the construction period (see Sections 2.4. & 2.5). A discussion of the user of paper specifications follows.

Validation of a paper specification was sought in the first set of DESSAC workshops. In this exercise groups of potential users were asked to:
• Read through and comment on a set of general user requirements.

• Read through and comment on, extend and prioritise the requirements specific to fungicides for winter wheat.

Being ushered into a strange room with people you don’t know and asked to read and comment on a requirement document is not something that many users would willingly volunteer for. The users in these trials did not seem to mind too much however as it formed a small part of the whole. One important lesson learned during the first of this series of events was that it is far better to give the document to a pair of users to discuss together, otherwise a definite ‘examination’ feeling creeps into the proceedings. This guideline was subsequently adopted for all workshops when a paper-based exercise was required. As commenting on a paper specification is not likely to enthuse users about the development, this activity is best included in a workshop which contains some more participative and interesting events i.e. brainstorming or prototype evaluation.

Paper prototypes are used when design ideas exist but they have not yet been developed into a computer-based prototype. Paper prototypes were, at one time, the only way to get feedback on ideas before beginning to write code. They are not used very commonly today as it is relatively easy to mock up screens on the computer, using packages like Microsoft’s Powerpoint™ and Macromind Director™. The incorporation into a workshop setting of a paper prototype would follow closely on the model suggested for the mock-up described below.

Mock-ups are prototypes of the interface and contain no actual functionality. Mock-ups were employed in the DESSAC and GRIME projects in the form of Director™ animations. These animations are extremely cost-effective to use in the early stages of design because they can be changed very easily and take relatively little time to produce. User opinions can usually be assimilated into the new design in a day. Another huge benefit of this technique is that it permits the developers to work through the consequences of their design choices before taking them to the user. A complex interface is very hard to visualise before it appears on screen. A great deal of the design decisions represented in the functional specification document for DESSAC were modelled in Director™ before being created in Visual C++ (the development language).
Obtaining user feedback on a mock-up requires the development of 'scenarios' and employs the concept of a 'walkthrough', both described in Section 2.4. The scenarios, or typical tasks the user would carry out on the system, are illustrated by 'walking' the user though the screens and menus and explaining what is going on at each stage. A typical workshop of eight or nine people would perhaps employ three computers and three facilitators to carry out this task, capturing user comments at each new change of screen. A cheaper method, and one which is becoming more commonly available, is to use a data projector and talk to the full group. One other person is employed to make notes on the user's comments in this case. This method was successfully adopted in several of the DESSAC design-stage validation exercises.

A full prototype has much of the functionality of the final system and can be used in a much more 'hands on' fashion by the workshop participants. For this exercise, adopted in DESSAC, GRIME and HORIS projects, 'scenarios', 'walkthroughs' and tasks are required. The scenarios and walkthrough is used in the same way as in the mock-up based workshop and user comments can be noted throughout or collected at the end. The aim in this case however is not to concentrate on the minutia of the screen and layout design (which is likely to have been largely settled at this point) but to show the users how the system is used. In effect, it serves as a mini training session. Tasks are used to encourage the users to play with the system and to see for themselves how it supports the decision process. Tasks should be as realistic as possible but fairly short and simple. This is another case when two or three computers are required. The facilitator does not necessarily need an additional hand as it is possible (if tiring) to move between groups. However, it is extremely useful to employ additional note-takers to record comments and the questions users ask as they use the system. The most common queries can later be used to provide 'topics' for the on-line help system.

As in all the previous workshops, it is important that the session end with a summary of the main conclusions of the day, and that these are agreed by all present. In the HORIS workshops the full group was re-convened after a coffee break, in which the facilitators listed the comments made in the smaller groups. The issues were then debated and requirements for change were summarised and prioritised. The latter always being a
useful activity as it enables the developer to make educated choices if changes have to be dropped through time or economic pressure.

Expert evaluation

An expert is someone who knows a lot about a particular topic. In this chapter an expert will be taken to mean someone who knows a lot about either the decision area, software design, or user interface design. Any of these people might be considered to be useful assets within the validation and testing process.

While the general rule is to employ new users for each workshop, there are times when access to ‘tame’ users is essential. Filling in small gaps in knowledge for example or asking for a snap judgement between two similar screen layouts. Tame ‘users’ may also be a political asset. In DESSAC, a group of leading players in the arable sector were chosen to act as guides and checks on the system development. Their function was to check that the system did not veer into unproductive waters and to provide a ready source of advice in-between workshops. Their involvement in the development of the system however also made several of them into project ‘champions’ and seemed to prevent several others from pursuing a policy of active detraction.

Computer scientists and human factors people can do much to increase the degree of robustness and user friendliness if they are invited to test the system before it is released in any of its forms. The full set of user questions contained within the requirements document can be used by either of these groups to test the conformance of the emerging system to its specification.

5.6.5 Maintenance

The final and frequently overlooked stage in DSS development, is maintenance i.e. the support and continued improvement of the system after initial release. A DSS is particularly susceptible to the ravages of change. Its models or databases may become out of date, as little as a few months after launch, as new science and new products emerge. The cost of, and mechanisms for, maintenance have to be considered at the feasibility stage and designed in to the system. Farmers and consultants in the DESSAC
and HORIS projects were particularly keen to know how developers were planning to maintain their product, possibly because of unhappy past experience.

Help and support is another area where previous DSS have disappointed their users (see Chapter 4.0). Modern users expect access to a 'helpline' in addition to any computer-based help provided. Experience suggests they also prefer a text-based document to the electronic version; unfortunately, this is an expensive option. The production of a manual is estimated to cost on average 10% of the average software project but it can be much higher (Leeds, 1999) and is gradually being phased out of mainstream use. Manuals are more often sold separately at high cost. The queries noted in the validation task can be used to provide 'topics' for the on-line help system.

Workshops may again be employed at periods after the release of software to gain an insight into and consensus on the main problems experienced by the users operating the software. These events can also be used to validate new releases and to gather data on the direction in which users would like to see improvements made. The form and content of these workshops will be very similar to those used in the validation task, with perhaps a longer period to brainstorm problems right at the beginning.

5.6.6 Flexibility of the approach

The main topics of interest listed for each of the development stages can be spread out over many workshop events or crammed into very few (see Figure 5.6). A relatively well funded and leading edge project such as DESSAC was able to start with interviews and then run many workshops and other validation events over a number of years. This ensured that many potential users were able to contribute to the design of the system.

In the final two years of the project the DESSAC project is validating the software 'in the field' i.e. farmers and consultants are being asked to use it within the business. This approach is regularly used in mainstream software production, as part of 'beta testing'.

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In the DSS context, it is very useful because it offers an opportunity to highlight and remove problems which cannot be identified in the artificial environment of a workshop validation exercise e.g. those relating to the integration of system use with other daily tasks.

HORIS, on the other hand, was a very low funded and short-term project. It was concerned with the development of an information system rather than a DSS but the principles of design are similar. It was able to begin with an existing system which demonstrated the approach considered by the developers (i.e. half way along the normal development pathway) and employed only two workshop stages and a postal questionnaire. The outcome from this minimalist approach was good: considerable interest was shown in the final product and sales are said to be healthy, although figures are not available for reasons of commercial confidentiality.
5.6.7 General principles for running workshops in agriculture

**Numbers**

Experience suggests that a good average size for an interactive group is around six or seven, it allows all team members the space to speak and to feel sufficiently anonymous to do so. Smaller groups (three or four people) also work well (Krueger, 1994). Research suggests that the majority of severe usability problems are identified by the first few users, and that 80% of problems are identified by the first four or five (Virzi, 1992). However, if a DSS is to be used by different types of user, e.g. farmers and consultants, each of whom may have their own ways of using the system, several of each type of user will be required.

**Who is a stakeholder?**

A stakeholder is anyone who has a 'stake' in the DSS i.e. anyone involved in contributing to the decision-making process. This includes indirect contributions e.g. a consultant may take the decision, but will have to explain it to the client who will have placed restrictions on the decision parameters.

**Sampling & representation**

Within the identified groups of interest there may be sub-groups which have to be represented. For example consultants are involved in most decisions relating to chemical use but there are three main types of consultant (ADAS, Independent and Agrochemical) and each have slightly different needs and requirements. Farmers and growers are also highly variable in their views depending on the size and nature of the enterprise and the part of the country in which they farm.

**Mixed or single-group samples**

Holding individual workshops for each of the main groupings, although more expensive, will identify much more information than holding several mixed events, as each group can focus on and give detail about its own perspective. Some groups are also less likely to mention problems in front of others e.g. farmers will not complain about supermarkets
if representatives from these very powerful buyers are present. A mixed group may be more appropriate however when discussing potential solutions to problems that run across group boundaries.

**How many workshops is enough?**

A major problem for system developers is lack of funds and short time-scales. A pragmatic view has to be taken if user-centred design is to be institutionalised into the very small project as well as the larger, better funded, ones. Three workshops, well spaced out through the design lifecycle (as represented in Figure 5.5) after feasibility, are better than none at all. A better 'minimum' plan is to have three 'sets' of workshops, each set containing a user group. It is better to space a few workshops out throughout the design lifecycle than to use all resources at one stage. A rule of thumb is to include as many workshops in the project proposal as possible and not see them as the 'soft option' when cuts have to be made.

**Summary of guidelines**

- Use new users for each task if possible
- Use 'experts' for interim design decisions
- Plan for 'out of season' workshops
- Three to nine users in a group (some individual, some group activity)
- Use role specific groups (e.g. farmers/consultants/retailers)
- Use postal questionnaires to validate key aspects
- Rapid prototype - paper, graphics package etc. before coding
- Document requirements/product specification (what is baseline)
- Document design solutions & problems

Agricultural DSS users:

- May not be role definable
- Are time limited in key parts of season
• Not in office very often
• Have very variable skills and interests
• Are not familiar with modeling
• Are very interested in financial information

5.7 SUMMARY OF PRACTICAL APPROACH

The first part of this chapter examined the requirements for a user-centred design method specifically tailored to the needs of the developer of an agricultural DSS. The ability of existing approaches to analyse the decision task were then explored: task analysis being a core component of the user-centred approach. Both traditional and cognitive task analysis methods were found to be inappropriate and lacking in detail when applied to decision-making and were therefore rejected for use in this case. The Decision Enquiry method proposed by Arinze (1989) was introduced as a viable and useful alternative. Attention was then turned to the method by which Decision Enquiries could be elicited from users in a flexible and economical fashion. The potential of workshops was explored and a number of arguments for its adoption as a basic device for user participation were presented. Finally a practical method which incorporates the task analysis and data gathering techniques was described.

The approach described in this section meets all of the requirements stated in Section 5.2 i.e. it specifies exactly how users are to be involved in the process, it is flexible, supports a wide variety of project sizes time-scales and funding characteristics and is relatively inexpensive. The user involvement is related to defined and recognisable project tasks and is clearly appropriate for decision support system development. While the arrangement of individual process components is novel, each has a track record for delivering what it has been selected to do i.e. workshops to provide cost-effective user input, decision enquiries to successfully inform the design of a DSS, and standard data collection and validation techniques such as brainstorming, interviewing, scenario development and walkthroughs to deliver user comment and feedback.
6.0 INTERFACE DESIGN FOR CROP PRODUCTION DSS

6.1 INTERFACE GUIDELINES & THE APPLICATION OF THE QUESTION APPROACH

This thesis supports the potential of DSS as a technology transfer mechanism if appropriate measures are taken to ensure their usability. The previous chapter outlined a flexible user-centred design method which, it is hoped, will provide a means for agricultural DSS developers to adopt a user-centred design approach within project constraints. It might be argued however that the structured approach alone does not provide sufficient detail. It does not, for example, provide guidance on the translation of user requirements into usable interface features.

The design of a usable user interface, while informed by the questions the user asks of a system, will not emerge fully formed from them. An understanding of user questions simply ensures that the developer pays attention to the features required, it does not point to the optimum placement of screen features or other necessary detail. Thus the adoption of the method outlined in the previous section still leaves scope for the developer to create usability problems for the user e.g. by making each screen very different from the last, overusing colour, using complex menu structures etc. In short, by being unaware of the knowledge gathered through experiment and trial on the best methods of ensuring interface usability the designer may reduce the effectiveness of the interface.

Hix and Hartman (1993) identify four main kinds of human factors document used to deliver this type of knowledge to the systems developer:

- User interaction standards
- User interaction design guidelines
- Commercial style guides
- Customised style guides

Each of these will be examined in turn before reviewing their place in a user-centred design approach for DSS developers.
6.1.1 User Interface Standards

Standards are official and freely available documents. They are rules which have been agreed, either within an organisation, country or other geographical or geopolitical unit, and which must be used when designing a product. Adherence to standards is regulated by contract or law. The main interface standard which should be considered when developing DSS for crop production is ISO9421, particularly part 12 ‘Presentation of Information’ (British Standards Institute, 1999).

While the adoption of standards should be encouraged, the utility of many of them is restricted by their generality. They draw attention to areas which developers need to consider but in many cases cannot be used directly to inform the interface design. As Hix and Hartman suggest, standards

"require much interpretation and tailoring to be very useful in user interaction design. ... they may be too vague and generic to offer effective guidance" (Hix, 1993 p. 19)

6.1.2 User Interface Guidelines

There are many documents which purport to provide more specific guidance on user interaction and user interface design. Some are based on empirical studies, others on observation or on in-house preferences. Examples of this type of guideline document are:

- Informal style of guideline document (e.g Gaines & Shaw, 1984)
- Formal guidelines for HCI e.g. Smith & Mosier (1986)
- Formal style specific and general guidelines (e.g Schneiderman, 1987)

Many of the more well known (in human factors circles) design guideline documents have become dated. e.g. Smith & Mosier (1986). They contain guidelines specific to the command style interface (e.g. MS-Dos) which prevailed until the late 1980’s. As the majority of developments in the 1990’s are based on the Windows/Desktop metaphor, the older guidelines are now of limited value (Maguire, 1990).
Human factors 'guidelines' have also been criticised for being vague and 'woolly' and hard to apply in a development environment. As they have been created for application across a broad spectrum of user interaction design they are often very generally worded, for example 'prevent user errors', which says nothing about where and how. This type of guidance is obviously unsuitable for crop development DSS developers whose need for specific and structured support is described in section 5.2.

6.1.3 Commercial Style Guides

Commercial Style Guides are commercially available documents produced by an organisation for the purpose of explaining the house style of a particular product or family of products. As Hix & Hartson explain:

'a style guide provides a much more concrete and useful framework for design than does a standards document.'

because it offers:

- a description of the objects in a system and their style of operation – both the look (appearance) and feel (behaviour)
- guidance on how and on when to use a particular style or object

The adoption of a commercial style guide is one way in which a DSS developer can obtain clear direction for the shape and structure of the user interface and user interaction. In the DESSAC project the decision to adopt the Windows guidelines document for Windows '95TM (Microsoft, 1995) was taken very early. This document incorporates most of the key guidelines contained in the human factors documents listed above and gives clear instructions on the general use and format of the major dialog boxes, windows and functions available to Windows '95 developers e.g. Figure 6.1
Chapter 6

Combo Boxes

A combo box is a control that combines a text box with a list box, as shown in Figure 7.19. This allows the user to type in an entry or choose one from the list.

![Figure 7.19 A combo box](image)

The text box and its associated list box have a dependent relationship. As text is typed into the text box, the list scrolls to the nearest match. In addition, when the user selects an item in the list box, it automatically uses that entry to replace the contents of the text box and selects the text.

The interface for the control follows the conventions supported for each component, except that the UP ARROW and DOWN ARROW keys move only in the list box. LEFT ARROW and RIGHT ARROW keys operate solely in the text box.

In addition to ensuring a common and consistent 'look and feel' to the user interface, the adoption of the Microsoft standard supports existing learning. As most of the user base for the DESSAC system are familiar with Microsoft products, less learning is required on the part of users if the DESSAC system adopts the same interaction style.

While providing a good deal more guidance in a practical and useful form, a commercial style guide may still not be specific enough to be useful to many DSS developers. While more specific than human factors guidelines, a commercial guide still has to be
applicable to a wide range of software applications; thus leaving a lot of leeway for developers to interpret the rules.

This may be ideal for the mainstream software producer keen to create a 'house style' for commercial and marketing reasons. However agricultural DSS developers, for whom software production is often a secondary occupation, will need much more specific guidance and 'handholding' if they are to be encouraged to develop truly usable systems.

Mainstream developers also have the advantage of a much wider, potentially more computer literate, and often less time constrained audience for their products than agricultural DSS producers. Many farm-based users need help to grasp and use the information within a DSS in the limited time they have at the computer screen. The seasonal nature of farm work adds the additional problem that large chunks of time may pass between each use of a DSS. The ease with which a product can be re-learned becomes much more important in this instance. These limitations on use and the restricted size of the market coupled with the nature of the funding basis for development make it critical that crop production DSS get it 'right first time', as the widespread and immediate acceptance of a system can be fundamental to its continued development and support. A simple commercial style guide is unlikely to provide the level of assistance required by DSS developers in this situation and there is a need to go a step further and produce a set of guidelines specific to DSS for crop production i.e. a customised style guide. In the DESSAC example it is also important that the modules it supports all share a common 'look and feel'.

6.1.4 Customised Style Guides

Hix and Hartman suggest that the development of a customised style guide is 'an important early activity' (op cit. p 24) for a development team. By drawing on existing guidelines, commercial style guides and their own past experience the development of a customised style guide tailored to their needs makes it easier for teams to produce consistent and usable interfaces.
The development of a customised style guide for crop production DSS would have many advantages, it would:

- provide a practical means of transmitting human factors knowledge and experience
- provide practical support for inexperienced developers
- ensure a consistency of approach across a range of DSS
- make use of past learning by users and thereby improve usability

and would go a long way towards improving the potential for acceptance of this technology in agriculture. The disadvantages of such a specialised document is that it is reduced in its range of applicability and could potentially stop design from adapting and moving forward. Steps would have to be taken to ensure the continued growth and development of such a document if it were to remain viable.

6.1.5 The case for a question-based customised style-guide

Standards should form the basis of any such guide as should core guidelines for ease of use e.g. consistency, simplicity, etc. described earlier. But how can a style-guide be made specific to crop production DSS? Does a suitably generic set of guidelines exist and if so how might they be structured for ease of delivery? In the previous chapter the use of questions, or decision enquiries were suggested as the basis for a user requirements and specification method. In this section the use of questions is again suggested as a method for identifying and structuring generic guidelines for DSS user interface design.

The generic nature of crop production DSS display requirements

The GRIME project identified several common features of the models underlying a decision support system which relate to the input and output of the model (Parker, 1996). On the input side models require data to be put into them (e.g. weather, crop, field data); data which has to be entered by hand or by a logging device, and requires facilities for viewing and editing. To meet this type of input requirement the developer has a need for
generic guidance on data input facilities, preferences and import set-up facilities (for selection of logging devices), viewing and editing functions.

Requirements for user input

As these types of activity are commonly required in other applications from word-processing to pay-roll, a commercial guideline resource may provide sufficient support. The selection of the Windows 95™ document for example provides methods and examples of screen layout for input and data entry screens (see Figure 6.2). Other examples based on the same style guide can also be found in many mainstream applications.

![Example of data entry screen from Windows Interface Guidelines (1995) p.232](image)

Figure 6.2 Example of data entry screen from Windows Interface Guidelines (1995) p.232

Requirements for user output

On the output side the results of model calculations have to be displayed to the user in a meaningful way i.e. one which supports the decision task. This is where the commercial style guide may not provide sufficient support as output is very application specific. The commercial guidelines will have to be general enough to cover a wide range of systems. To provide specific support for output feature design it is necessary to return to the notion of ‘task’ for decision support systems.
In the previous chapter the ‘tasks’ which DSS support were defined in terms of the questions asked by the user when engaged in the decision-making process. In Arinze’s taxonomy these are divided into three main types, State, Action and Projection enquiries. It has been shown that the questions generated during the requirements survey for DESSAC fall comfortably within these divisions. That this is also true of requirements from other crop production sectors can be supported by evidence from the GRIME project.

**Consistency between sectors**

In a GRIME internal discussion document circulated by the author in 1994 (see Appendix N) the need to support two generic tasks for horticultural DSS was described: working back from a market requirement to get a plan, and working forward from a current position to get a prediction. These descriptions are directly equivalent to Arinze’s Action and Projection categories.

It is also possible to see similarities between the two sectors at a greater level of detail as Table 6.1 illustrates:

<table>
<thead>
<tr>
<th>Table 6.1: Typical questions elicited during DESSAC and GRIME requirements analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DESSAC (arable)</strong></td>
</tr>
<tr>
<td><strong>Action</strong></td>
</tr>
<tr>
<td>What do I do to solve this problem?</td>
</tr>
<tr>
<td>What is the best strategy for this field/variety?</td>
</tr>
<tr>
<td>What future steps do I take to avoid disease?</td>
</tr>
<tr>
<td>What products/dose should I use for the best cost benefit.</td>
</tr>
<tr>
<td>Can I delay my ‘flag-leaf’ spray until GS59?</td>
</tr>
<tr>
<td>What will happen if I change any of the options e.g. chemical choice/dose etc</td>
</tr>
<tr>
<td>What will happen if weather does X</td>
</tr>
<tr>
<td>What will happen if disease pressure does Y</td>
</tr>
<tr>
<td>What will the crop look like if I do this</td>
</tr>
</tbody>
</table>

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While basic differences do exist between sectors (horticulture is driven by quality and the need to provide a consistent product over a season whereas arable is driven more by gross margin considerations) many of the core questions are the same. It may be necessary to provide a greater level of detail on some questions for different sectors, or bring certain types of information to the surface but the basic guidelines for output display should be identical.

It is also true that DSS for different tasks within the crop production sector, e.g. pest, disease, irrigation, nutrition, DSS will share many common requirements. All support a time-based process in which the progress of the crop on a set of variables has to be monitored, and in all cases this will require some pre-season planning, within season monitoring and periodic adjustment. The classes of questions asked by a user during all of these activities are therefore likely to be the same.

**Consistency across user groups**

There are many potentially differentiable categories of user within crop production e.g. distributor consultants, independent consultants, farmers, growers, etc., each with their own potentially differing sets of requirements and levels of expertise. In classic user-centred design approaches the needs of these users might be considered individually, resulting a several different interface designs. This type of differentiated approach does not sit well with the idea of a set of generic interface guidelines in which one design suits all.

In fact such divisions do not suit the development of DSS at all well. It is extremely difficult to make a clean division between the requirements of crop production DSS users on the basis of their job descriptions. As Figure 4.1 in Chapter 4 illustrates, there is no clear distinction between farmer and consultant in the spray planning decision process. Farmers may take most of the practical day to day decisions and consultants most of the scientific decisions, but there are scientific farmers and practical consultants who do almost everything making it very hard to divide requirements on a role basis. It is much easier and more appropriate to look at the decision task independently of the user group and make sure that all aspects of it are covered by the system design. This type of approach accords with the notion of generality required by a crop production DSS style guide.
The question-based approach as a structure for the style-guide

If it is accepted that there is a need for a detailed and tailored style-guide for the developers of crop production DSS, and that there is sufficient generality in requirements from the various sectors of the industry to make such a tool useful, then the question remains as to how to source, gather and structure the materials within it. To keep the discussion simple it will be assumed that the guidelines will be delivered on paper, much of the basic structure could however be delivered in any form including on-line HTML.

Most style-guides are structured according to the topics they contain and a good guide will allow the reader to focus quickly on a topic of interest by scanning the list of contents. The same type of mechanism is required if the DSS developer is to be able to find relevant design information quickly and effectively. The previous chapter introduced the notion of the user query as the basic task component and as a basis for requirements analysis and system specification. This chapter has shown that there are a number of questions which appear in all sectors and which apply to all DSS. It is therefore proposed that identification of these questions will provide a suitable framework for the collation and delivery of user interface guidance.

A style guide of this type could also provide 'off the peg' solutions for DSS developers. While no single design can be taken to be absolute and perfect for all situations a lot of time and effort might be saved if design solutions, which have some support in terms of user acceptance and human factors research experience, were gathered together and made available for use by developers.

The purpose of the next section is to describe an initial set\(^\text{19}\) of generic requirements for crop production based on Arinze's enquiry categories. The final section will look at what exists in the way of design solutions and guidelines to support the answering of these queries.

\(^{19}\) It being recognised that it is beyond the scope of this thesis to compile a complete set.
6.2 GENERIC REQUIREMENTS FOR CROP PRODUCTION DSS INTERFACES

The structure of the next two sections is closely related. In this section the requirements for crop production DSS are described and in the next (Section 6.3) a design solution is proposed to meet each of the stated requirements.

6.2.1 Meta-requirements

While the rest of this section is devoted to requirements phrased within the decision enquiry format, work within the GRIME and DESSAC projects has identified a set which support the task process rather than the task itself. Operating at a higher level than questions these ‘meta-requirements’ are explained below.

Immediate access to season-critical information

The most critical period for use of a crop production DSS is during the season when the crop is actively growing: this is the point at which decisions have to be taken very quickly and there is little time to research or to sift through information. Decision support systems are also important during the planning task of the year but it is during the growing season that information is needed fast and decision support on tap is most useful. In these circumstances the crop producer’s need for information is very similar to that of operators in process industries. There is a requirement to monitor performance against an ideal outcome and make changes as necessary. Unlike the average manufacturing process engineer however, the farm user is rarely in the farm office and in sight of the computer. The first requirement for the display has therefore to be to provide rapid access to the most important information for monitoring and decision-making: to ensure that the user can see ‘at a glance’ where problems may occur and why. The importance of speed and immediacy to the farm user is illustrated by this quote from a user in the interface evaluation task of the GRIME project

'scientists have eight hours a day to play with it (the model) and farmers only have five minutes' (Parker, 1996a).
Access to explanation

The second meta-requirement is the provision of access to explanation. Crop producers, in common with many people accustomed to taking their own decisions, are particularly suspicious of answers coming out of a ‘black box’. This view is also supported by Chen (1992) who states that:

"The decision-maker has dual responsibility: he is responsible for the decision, but also for providing information to the system which can be understood by it. If the decision-maker lets the intelligent decision support system make some of the decisions (and often he has no choice in the matter), he must be able to get an explanation from the intelligent decision support system that he can understand in order to agree or disagree with the intelligent decision support system." (Chen, 1992)

While the degree of detail will vary with the level of scientific background of the end-user, there will always be a requirement on the DSS to provide access to an explanation of the way in which a solution is reached.

Layering of information

The third general requirement for interface design emerged during the DESSAC design process when a means was sought to meet the needs of the many different types of user to be accommodated by the system. In particular there was a need to provide sufficient scientific information to comfort those who needed to know exactly where the data underlying the models had originated from, while not overwhelming anyone else. The concept that emerged from these discussions was called ‘layering’. Only information immediately required by the user is presented at the interface surface. Other information sought by specific types of user is included in the system but at differing levels of access i.e. no mouse clicks required to get at most important data, one to get at next level of importance and so on until the most obscure information layer is reached (e.g. original scientific papers).

The rest of this section discusses questions relating to crop development which can be considered generic under each of Arinze’s headings and explicitly states the requirements for display which result.
6.2.2 State enquiries

**Generic questions**

State enquiries are concerned with monitoring and require the interface to display the value of important variables in a form which will allow the user to ask: ‘What is going on in this field/block, what is its current status?’ and ‘What is the risk from this state of the system?’. The latter is a particularly important part of the decision support process. Providing a statement of risk allows the user to judge whether to take action in a given situation. The means by which risk is calculated should always be made clear as user’s needs to be reassured that the model is using the same type of logic to assess the situation as they themselves would. There is usually an economic aspect to a farmer/consultant user’s understanding of risk; for example in the DESSAC Wheat Disease Manager system, risk is defined as the ‘risk of disease induced economic loss’.

**Generic requirements at the interface**

- a) Display risk status (for a range of potential problems)
- b) Define risk and the process of its calculation.
- c) Display status over time.
- d) Display status and risk for a range of units e.g. fields, blocks, farm, farms

6.2.3 Action (reverse what if) enquiries

**Generic questions**

The core action question is ‘how do I get to state x from here’: in horticulture this may require more detail at the interface than in arable production. Arable crops are harvested at one point in the year. Horticultural crops can be harvested for a much longer period (and stored for later supply e.g. apples, white cabbage etc) and the aim is to be able to supply a steady stream of a crop at a uniform level of quality. In arable and other combinable crops the question is likely to be ‘how do I obtain the highest value
marketable product for least cost’. In horticulture the question is more likely to be 'how do I maintain this profile of supply, for this quality of crop, over this period'\textsuperscript{20}.

In vegetable and fruit production there is an additional emphasis on quality and on the size and shape of the crop. Quality always has to be high but there may be different market niches for products at different sizes or shapes further complicating the interface display. Carrots for example have to be of high quality, of a uniform size and straight to get a premium price. There is however also a market for 'baby carrots'. A grower might be interested in how to ensure a consistent supply of both sizes of carrot throughout the season.

**Generic requirements at the interface**

Despite the differences between the groups the following generic requirements can be identified:

a) Display the projected movement, over time, of the variable of interest i.e. 
   - the expected development of the crop according to the variable of interest 
   - the expected development of pest or disease 
   - expected levels of nutrition or water in the soil at various levels 
   - the impact of control measures 

b) Display the uncertainty associated with the projection on the variable of interest e.g. 
   Extent of variation in target yield, margin, crop size, crop quality 

c) Display the actions required to achieve the desired outcome

\textsuperscript{20} This is also true of top fruit. The profile of supply has to be met, at a given standard even though the product is managed within store rather than in the field. There is a keen interest in store management DSS in the top fruit sector.
6.2.4 Projection (what if) enquiries

**Generic questions**

The core question here is 'what will happen to the crop from this point on given this set of circumstances'. When 'what if'ing, crop producers play with possibilities in a search for an optimum solution to their current needs. They will ask how one solution differs from another and on what dimensions. They will need to know what data has been used to make the projection and how much reliability they can place on it. They may also ask whether one solution is significantly different from another. The key output for comparison purposes is likely to be margin and yield in arable crops and quality and margin for horticultural crops.

**Generic requirements at the interface**

This results in a set of requirements which overlap considerably with those from the Action questions. As both make use of the same underlying model this is not really surprising. There are some specific differences however.

a) Display the projected movement, over time, of the variable of interest i.e.

- the expected development of the crop according to the variable of interest
- the expected development of pest or disease
- expected levels of nutrition or water in the soil at various levels
- the impact of control measures

b) Display the uncertainty associated with the projection on the variable of interest e.g.
   Extent of variation in target yield, margin, crop size, crop quality

c) Display the actions required to achieve the desired outcome

d) Display the data used in the model's calculations and its source

e) Support the editing of all variable values which have a bearing on the outcome of the DSS model
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f) Support the comparison of potential solutions on the variable of interest (margin, yield, size etc)

g) Provide a relevant assessment of outcome for comparisons (e.g. financial & yield terms for arable crops and quality/financial terms for horticultural crops.

6.2.5 Summary of generic interface requirements

The requirements for interface feature listed in the previous sections are summarised below:

- Provide rapid access to monitoring data
- Provide access to explanation of model output
- Layer information with the most detailed at the lowest level
- Display risk status
- Define risk and the process of its calculation.
- Display status over time.
- Display status and risk for a range of units e.g. fields, blocks, farm, farms
- Display the projected movement, over time, of the variable of interest
- Display the uncertainty associated with the projection on the variable of interest
- Display the actions required to achieve the desired outcome
- Display the data used in the model's calculations and its source
- Support the editing of all variable values which have a bearing on the outcome of the DSS model
- Support the comparison of potential solutions on the variable of interest (margin, yield, size etc)
- Provide a relevant assessment of outcome for comparisons (e.g. financial & yield terms for arable crops and quality/financial terms for horticultural crops

Some guidance on the creation of interface features is provided in the following section using examples from DESSAC and GRIME.
6.3 GENERIC SOLUTIONS

The subsections below address each of the requirements listed in Section 6.2.5 in turn.

6.3.1 Provide rapid access to monitoring data – ‘one stop’ window

The initial idea of creating a display which contained all the monitoring and associated information required by the user was conceived by the author within the GRIME project.

Figure 6.3 shows the main screen for a suggested generic horticultural decision support environment.

![Figure 6.3: The ‘one stop’ window as envisaged in GRIME](image)

The bulk of the screen area is reserved for a display of the value of the main variables over time. The dark vertical line represents the current date. The activity of weather variables, model variables and spray events is all represented in this space. The areas around this space are designed to contain all the associated information to which the user might require immediate access when exploring the decision space. They serve the
additional function of making the source of the data feeding into the display immediately obvious.

A diagrammatic representation of the GRIME design can be seen in Figure 6.4.

![Diagram](image)

**Figure 6.4: Layout of GRIME Interface design**

The window is essentially divided into three functional areas, the main viewing area and access to models form two of them and the third provides access to quick means of changing inputs to models and to the display.

This idea was developed and refined within the Wheat Disease Manager module of the DESSAC system. Figure 6.5 emerged from the project’s iterative design process as the result of considerable debate and consultation with agronomists, farmers and consortium partners.
The function of the screen, to provide immediate access to essential information, has not deviated from the original GRIME design. The layout and structuring has however undergone considerable refinement and incorporates the ideas of many people, although the main design work was carried out by the author and the interface developer, Simon Beaulah, then of the Silsoe Research Institute.

The DESSAC screen is divided into four not three functional areas and the emphasis has changed. The main monitoring area, called the ‘spray plan area’ in Figure 6.6, still takes up most of the screen and is still bisected by a bar indicating the current date. Information to the left of this line relates to activities in the past and information to the right to forecast or planned activities.
In the Wheat Disease Manager fungal diseases which might affect the crop are listed on the left of this area and potential risk from them is highlighted. In Figure 6.5, risk is shown from Yellow Rust and from Septoria tritici. The risk, yellow for moderate and red for high, is the risk for each day of a disease event occurring which will result in economic loss. A yellow block therefore indicates that there is a moderate risk of economic loss resulting from disease occurring on that day.

Supporting information has been considerably re-organised in the DESSAC system to provide access to the essential data without over complicating the screen design. In this layout information which is associated in time with the spray planning data is presented in a linked and tabbed area below it. Tabs are used to enable a range of critical information to be immediately accessible. Figure 6.5 shows the weather data associated with the display; rainfall events linked to the risk of Septoria tritici can be clearly seen.

For arable farmers the requirement for associated information on this screen was for a display of weather (Figure 6.9), growth stages (Figure 6.7) and for a display of the effect of disease on the canopy (see Figure 6.8). The latter also serves as a visual representation of the predicted effect of disease generated by the underlying model.
The area to the right of the spray planning area contains a display of the impact of the predicted level of disease on the margin over treatment costs and yield of the crop in question. Although omitted on the original GRIME screen the impact of disease on quality, and in turn on profitability, if at all quantifiable is a useful display item.

Spray activities are shown in Figure 6.5 by a two headed arrow, but serve the same function as the small red triangle employed in the GRIME display (Figure 6.3) i.e. of showing the point at which an application is made and allowing it to be dragged to new
dates by the user. The impact of the spray activity is shown in the DESSAC screen as a spreading area of green varying according to its effectiveness on each disease. As products have an impact on disease development from events in the past (erradicant effect) as well as a protectant value in the future the green spreads in both directions. In the GRIME display this effect is shown as a change in the percentage of disease or pest on the graph layout.

This display is dynamic and any changes to variables through time or ‘what if’ activities will immediately update the screen components.

The GRIME interface was preferred to a series of more conventional windows by users during the interface evaluation period of that project (Parker, 1996a) and has been considerably improved since within the DESSAC project. The success of this format is evidenced by the ease with which it has been accepted by those involved in the extensive series of workshops and in laboratory-based trials (see Section 3.4.6 and Appendix H).

The most recent indicator that the layout works is provided by the initial training sessions for DESSAC field-based trials. During these sessions a high percentage of people commented on the ‘friendliness’ of the user interface and its intuitive nature. Given the complexity it presents to the non-farm user these comments are very telling and suggest that the design is well tuned to the specific needs of its intended user group.

Although the layout of the DESSAC interface differs from the original model developed for horticulture it seems entirely feasible that the DESSAC layout would be applicable to horticultural as well as arable crop problems. This is however an area in which more research is required.

6.3.2 Provide access to explanation of model output

The requirement to provide access to explanations of model output, while recognised, has yet to be fully developed within the DESSAC Wheat Disease Module. Its place in the system is indicated by an icon on the toolbar, here shown as a set of scales representing the ‘justice’ in justify. In the current version of the system selection of this tool opens up a text viewing system called the ‘browser’ on a page
containing a scientific paper on the model. Thus it provides some form of explanation for the interested user but does not really meet the needs of the average user. According to the concept of layering discussed below this level of detail should be accessible but at a level lower than a more understandable and simple form of explanation. At the highest, simplest level the process by which the model arrives at its conclusion should be described step by step (possibly in an animated display) and the contribution of each of the variables the user is required to enter made clear. The latter point is essential if the user is to build up a good mental model of the way in which the DSS operates. It also serves to educate the user by providing a means of obtaining a more detailed understanding of the mechanisms by which a biological system operates.

6.3.3 Layer information with the most detailed at the lowest level

To date only two layers of information have been designed into the DESSAC system and therefore it is not possible to provide clear examples of layering in practice. The one recognised place in which this will take place in the final system was described in the previous section and is illustrated in Figure 6.10.

![Figure 6.10: The concept of layering as applied to the 'Justify' dialog](image)

Other potential areas for layering are also concerned with the explanation of the science. For example the reason for the selection of a particular dose is provided by the ‘Fungicide module’. Selection of the graph shaped icon on the toolbar brings up the window displayed in Figure 6.11. From this the user can see the logic behind the choice. Should they wish to go further and ask what trials contributed to the creation of this curve...
a further mouse-click (button not shown here) should take them to a listing of trials, their
dates and sources of funding. Another might take them to details of individual trials.

**Figure 6.11: Early design idea for the fungicide performance screen**

### 6.3.4 Display risk status

All crop-based DSS need to be able to offer the user some indication of the outcome of
their strategies and for most this will be in terms of the risk associated with a given
approach. Risk is however very specific to a decision and to personal interpretation.
High risk for one person may equate to a medium level of risk for someone else e.g.
paragliding may be considered an unacceptably risky sport for some and quite acceptable
for others. The choice of a risk display for the DESSAC WDM system was a protracted
and intensively-debated topics and a range of potential designs were created, discussed
and abandoned. The need to fix on something which would be universally perceived to
equate to risk by all users finally resolved into a definition based on economic loss. In this approach the potential impact of a possible disease event on the resulting margin over treatment costs for a given field is displayed.

The debate about displaying risk calculated on this basis also generated a number of design ideas including one which displayed percentage risk on a graduated grey-scale over time (b in Figure 6.12) and another which used blue, yellow and red circles to indicate disease events (c in Figure 6.12) and yet another which used a graphical display.

![Figure 6.12: Showing early ideas for indicators of risk](image)

**a)** 'Molehills' indicate extent (width) and effectiveness (height) of fungicide cover, 'blobs' indicate existence of and severity (height) of disease risk. The aim being to ensure that areas of risk are covered by molehills.

**b)** Risk and cover are both represented by differential shading of day length units, the darker the shading the higher the risk/or greater the cover. The aim being to ensure a match between risk and cover.

**c)** Other forms of risk and cover indicator.

Graphical displays (Figure 6.13), while familiar to and appreciated by the more scientifically inclined users, were an immediate 'turn off' to others (Parker, 1998). The final design (Figure 6.5) simplifies the screen considerably by only displaying events which were considered important by consultant agronomists i.e. over one of two threshold values.
The colours yellow for moderate and red for high risk days make use of existing associations with danger. Risk below the ‘yellow’ threshold level was considered by agronomists to not be worth displaying. Thresholds are defined mathematically by the model.

The design illustrated in Figure 6.5 has met with widespread support from user groups (evidence from laboratory trials – Section 3.4.6 and opinion from user groups in recent demonstrations of the software) as it provides an immediate and clear indication of potential problems. The provision of a graphical display as an optional ‘view’ was considered but has had to be abandoned in order to meet delivery deadlines.

6.3.5 Define risk and the process of its calculation.

In the DESSAC Wheat Disease Manager the definition of risk (described in the previous section) can be accessed by the user through the use of ‘tool tips’ and context-specific help. Passing the cursor over the risk display will give a short description (Figure 6.14); using the context-specific help indicator will call up a much more detailed description (also in Figure 6.14) and link into the full model explanation described earlier.
The algorithm for risk was defined and coded in a collaborative effort between Silsoe Research Institute and ADAS. It is being tested in the final two years of the project (i.e. 98/99 and 99/2000 seasons).

6.3.6 Display status over time.

Time for the farmer and consultant can be viewed in the same way as the length of a production track for the industrial manufacturer. As the crop moves along the time belt various events occur which make it more or less fit for its market. In the same way that a process engineer wants to know what is happening to the product at different points along the production line the farmer and consultant have a need to view the status of the crop at different points along the time line.

It may also be necessary to define and indicate key points along the line. The display solution employed in the GRIME and DESSAC screens is to show events occurring over a time period and to provide an indication of that time period (see main screen Figures 6.3 and 6.5). The screen displays a period of approximately four months and covers the growth stages critical to the application of fungicides. The time-line here is shown in weeks. The range and units in which time is displayed will vary according to the topic of the decision; many horticultural growers operate in week numbers for example, not actual dates, and are interested in a period longer than four months. As each type of time unit (dates, week numbers, growth stages, etc.) is related to the others there should be no
reason why the user cannot choose the scale appropriate to their needs. In the DESSAC system this option is indicated by the pull-down box on the side of the display indication.

![Pull down box for changing time units](image)

Figure 6.15: Pull down box for changing time units

The facility to scroll through time is provided by simple scroll bar operators in the DESSAC system. The user’s current position in the timeline is indicated by a vertical line and a date display, a single red line in the GRIME display and a split bar in DESSAC. The split allows the values for the current date to be framed rather than obscured by the indicator.

![Suggested preferences dialog for Wheat Disease Manager](image)

Figure 6.16: Suggested preferences dialog for Wheat Disease Manager
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The ability to set the number of months framed by the display can also be made user-definable via a preferences option (see Figure 6.16) or via some form of screen selection option (not used within DESSAC).

6.3.7 Display status and risk for a range of units e.g. fields, blocks, farm, farms

The means by which a which fields can be ‘blocked’ or farm data displayed was not addressed in the GRIME project but considerable thought has been given to it within DESSAC.

Fields are often grouped together in blocks which are treated as functionally equivalent units i.e. they are producing the same crop and variety and were planted at the same time in the same area. These blocks are treated as one as they will suffer the same risks at the same point and can be sprayed at the same time. In the DESSAC Wheat Disease Manager (WDM) the blocking process is assumed to have occurred prior to the data being used by WDM; as blocking is generally applicable to a wide range of decisions and not just one. Support for creating blocks or for splitting fields into smaller units (common in horticulture) is therefore not provided.

The requirement to display status for a field, unit or block has already been described. Support for viewing status over a farm or group of farms is provided within DESSAC by the window shown in Figure 6.17. Here the object of interest, spray applications in this case, is summarised for each field, block or unit over the area of concern (farm).

The requirement to display risk for a field has also been described. The risk display in the ‘farm view’ in Figure 6.5 is provided simply by the summary of margin and yield data on the right hand side.

Another display which was designed within the DESSAC project but which may not be delivered for reasons of computational complexity is the ‘status report’. In this view, suggested by Figure 6.18, the user is given an update of the status of all fields, blocks or units on the decision areas covered by their installed DSS.
Figure 6.17: Summarising spray plans and margin over the farm unit

Figure 6.18: Status report dialog
6.3.8 Display the projected movement, over time, of the variable of interest

Variables of interest in the DESSAC Wheat Disease Manager (WDM) are spray applications, disease progress and the health of the crop.

Spray applications by their nature are fixed in time but their effectiveness is not. The display of spray effectiveness on the diseases of interest is represented in WDM by areas of green, fading into nothing on either side.

Disease risk is shown by the yellow and red blobs discussed above but the projected progress of the disease and crop health is provided by the tabbed display shown in Figure 6.8. The yellow areas of the leaves on stylised wheat plants illustrates the extent of diseased tissue on the leaf layers.

6.3.9 Display the uncertainty associated with the projection on the variable of interest

Section 3.4.7 describes the research carried out under the DESSAC project into the best way of displaying uncertainty to the user. To summarise here, uncertainty may arise from a number of sources and can have a strong influence on decision-making. In decision-making under uncertainty, it is hard to determine what the 'optimum' alternative is, and the possibility of error due to poor choice increases. To take good decisions under these circumstances requires that the decision-maker is made aware of the degree of uncertainty surrounding each alternative, and ideally the potential for loss associated with it.

A survey was conducted to try to identify guidelines for the presentation of this type of data to the non-expert user. The research resulted in the production of a two stage mechanism for storing and retrieving design guidelines on this topic.

In the first stage the data behind the display item is examined. If it is judged to be of a vague or textual source then the display should also be in a textual form. If the data is from a precise source e.g. from a mathematical model then the form will be either graphical or tabular. The choice between these two is more difficult because the
literature is very divided in its findings when these forms are compared. The one common finding being that the choice of optimum display is highly task dependent.

As this thesis has argued for the use of questions instead of tasks in the DSS context the next step in the process is to define the user’s questions for the display in question. In the case of the displays used in the Wheat Disease Manager the questions were defined as:

1. What is the most likely outcome (in terms of margin & yield) with this alternative?
2. What is the worst possible outcome (in terms of margin & yield) with this alternative?
3. What is the best possible outcome (in terms of margin /yield) with this alternative?
4. What is the size of the spread of uncertainty around the most likely outcome?
5. How does the mean and spread in this alternative compare to others?

The results of the literature survey to these questions were applied. The study by Ibrekk and Morgan (1987) provides a solution to the first four questions. The spread of possible
outcomes and the range from best to worst is best represented by a shaded bar display. The most likely value is best represented by a display which explicitly represents it. These recommendations are incorporated into the display shown in Figure 6.20. The fifth question is explicitly addressed in Section 6.3.13.

Figure 6.20: Design solution to the DESSAC uncertainty display problem

In the design solution displayed in Figure 6.20 the shaded area (green on the screen) illustrates the spread of possible outcomes and the dark triangle on the left of the display is an explicit representation of the most likely outcome.

Figure 6.21: Example of the use of the spread display within Wheat Disease Manager
This mechanism is repeated in all windows where a spread of possible values around a most likely outcome is required, see Figure 6.21 for another example.

6.3.10 Display the actions required to achieve the desired outcome

In the case of the DESSAC Wheat Disease Manager which contains a decision model the data exists to meet this requirement. However some DSS will simply describe the situation as it is and after the user specifies actions i.e. they allow ‘what if’s’ but not reverse ‘what if’s’.

The decision model in the Wheat Disease Manager tests a large number of potential spray plans and presents the user with the top ten ranked in order of the margin over treatment costs they afford. These are displayed in the window illustrated in Figure 6.22.

![Figure 6.22: The optimisation dialog](image)

The spray events are indicated by the triangles placed at appropriate dates along the time line. The area on the left displays the products used within these sprays. Double clicking on the triangles reveals the suggested dose. Thus the two seemingly equivalent plans for Opus use slightly different doses. Users really want to see all of the information on the
screen but, to date, it has proved impossible to provide a means of doing so without making the information crowded and unreadable.

**Figure 6.23: Optimisation screen with variation bar**

Given the variation around the most likely outcome the top five or six of these plans are statistically equivalent. Some method is required to indicate this to the user or they will simply pick the top plan as being 'the best'. In a recent user workshop a consultant suggested the use of a band enclosing the range of the top option and extending down the list, this would immediately highlight those plans which fell within the same boundaries and those outside e.g. Figure 6.23. Another suggestion was to make all plans with no significant difference display the same mode and range. Further work will be needed to decide between these options.
Selection of a plan will place spray ‘arrows’ on the timeline as illustrated in Figure 6.24.

6.3.11 **Display the data used in the model’s calculations and its source**

Two methods are employed within the DESSAC system to support this requirement. The data used in the model’s calculations is accessed via the ‘inputs’ button on the bottom right hand corner of the screen. Figure 6.25 illustrates the type of screen which is envisaged will eventually appear here. It contains all of the model inputs.

Context sensitive help accessed from this screen will provide the user with details of the source of each of the default values.
6.3.12 Support the editing of all variable values which have a bearing on the outcome of the DSS model

The Wheat Disease Manager dialog illustrated in Figure 6.25 is completely user editable. The user will be asked if they want to save changes made to the default data in this screen when leaving the session rather than changes being saved automatically. This avoids ‘play’ data overwriting real data in the crop data system.

The original design idea in GRIME was that all screen values could be altered by direct manipulation i.e. weather values and spray icons could be dragged into new positions to support easy ‘what if’ manipulations. The DESSAC design has retained the drag properties of the spray icon but abandoned that of the weather. Users move the icon to a new position and select ‘run’ to re-run the model.

The relative weightings of all the variables, necessary to support the user’s mental model of the system, is provided in Help.
6.3.13 Support the comparison of potential solutions on the variable of interest (margin, yield, size etc)

Figure 6.26: One of the ways of viewing and comparing ‘what if’ outcomes.

Figure 6.27: Comparison of spray plans over the farm
A number of screens within the DESSAC Wheat Disease Manager support the comparison of potential solutions in terms of their margin and yield. These are the two main variables of interest to the crop producer concerned with wheat fungicide applications.

![Figure 6.28: Comparison of previous 'What if' analyses](image)

Figure 6.26 shows the comparison of spray plan options from a decision model run, Figure 6.27 the comparison of spray plans over the farm and Figure 6.28 (and figure 3.11) the comparison of previous ‘what if’ analysis.

### 6.3.14 Summary

This chapter set out to explore the possibility that a further layer of support could be provided for developers in the effort to bring a user-centred design approach to crop production DSS. Standards and style guides, while having a place were felt to be too general to be of use in these circumstances. A case for the creation of a customised style guide, based on the nature of the decision task, was made using questions as task units. The chapter illustrated that a number of ‘decision enquiries’ are generic to both horticultural and arable sectors and suggested that these be used as the basis for the guide. The selection of design ideas presented in the final section provides an example of the way in which such a guide could serve as a source and repository for good, well tested, interface ideas.
Chapter 7

7.0 SUMMARY AND CONCLUSIONS

7.1 SUMMARY OF THESIS

The main thrust of this thesis is that there is a problem with technology transfer in crop production (Section 1.2), that DSS are a suitable mechanism for solving it (Section 1.4), and that a user-centred design (UCD) approach is critical to the successful adoption of DSS by the industry (Section 4.3). The argument suggests that it is not sufficient merely to point DSS producers in the direction of user-centred design, but to furnish them with adequate methods and tools to achieve this goal, bearing in mind their specific requirements and limitations (Sections 5.1 & 5.2) and the nature of the decision support task (Section 2.3.6). The thesis proposes that none of the standard methods exactly meets this requirement (Section 2.5, Section 5.2.2) and that a new approach is needed. Arinze’s Decision Enquiry approach is introduced and supported as a means of addressing the problem (Section 5.4). Based on this, Section 5.3 and Sections 6.1-6.3 describe a UCD method and a means of supporting interface design which could be used to facilitate the development of useable DSS for crop production.

The focus of the discussion has touched on a number of disciplines and research areas. It is customary for a thesis to illustrate background knowledge of the fields of study in which the focal theory is set. This leads to rather more background material, in this case, than might normally be expected. Section 1.1 has described the structure of scientific communication structure within crop production. Section 1.3 described and defined DSS and gave examples of their use and purpose. Chapter 2 provided background to system development methods, both to ground the proposed UCD method in its theoretical context, and to provide support for the use of tools and techniques described in the contributing project work.

Much of the data theory for the thesis has been provided by a number of publicly funded collaborative research projects undertaken during the five years of the doctorate. As each project’s remit differed from that of this thesis, and also generated considerable amounts of documentation, a summary of each project rather than the full text was included. The
broad aims of each project, or component thereof, and the specific role of the author within it were described in Chapter 3, as were the approaches adopted to meet project goals and the results they obtained.

7.2 CONCLUSIONS

This thesis combines three distinct topic areas, crop production, decision support systems and human factors. The primary problem addressed by this work is the failure of technology transfer in crop production and it is here therefore that this thesis makes its main contribution. It is not however in the application of DSS as a solution to the problem, which is not original as others have been suggesting the use of this technology for some time. It is in the clear definition of the problem area and in the analysis of the value of Decision Support Systems in the face of evidence that they are not achieving the goals set out for them. It is also in the analysis of the reasons for DSS failure and finally, it is in the presentation of solutions intended to support future success.

In the following sections the contribution made to each of the three topic areas by this thesis are discussed in some detail. The aim of is to demonstrate how the work described in the previous chapters has made a difference to the starting state of each.

7.2.1 Contributions to the technology transfer process in crop production

This document extends the theory that Decision Support Systems could be valuable tools for the dissemination of scientific knowledge within the UK crop production industry. In addition to a general description of the function of DSS in general and the uses to which they have been put in several sectors (Section 1.3.4), this document provides evidence of their successful use in agriculture (Section 4.3.2). Specific ways in which DSS can be beneficial (i.e. supporting the increase of profits, maintaining quality,

21 The publication of a paper based on Chapter 4 of this thesis in Farm Management (Parker, 1999) is one way in which the material collated here will contribute to an increased understanding of the utility of well designed DSS as technology transfer tools.
manipulating crop characteristics and reducing inputs for crop producers) are also described (Section 1.4)

While DSS have been adopted as a means of transferring model-based information to farmers and consultants for some years, there has been little actual analysis of their potential within the industry, with the exception of an article published by Cox in 1996 (first discussed in Chapter 4). Cox argued against the use of DSS on the grounds that, while models are a useful aid to improve scientific understanding, they do not translate into useful farm tools. The main thrust of his argument was that the systems he surveyed were developed in isolation of the decision-making process, and decision-making environment, in which they were intended for use.

"There is an implicit assumption that a DSS provides the best available information, and that this is sufficient justification for its development and for promoting its use. This is rarely based on a previous understanding of the problems decision-makers face; nor of how they are handling them now; nor of how this particular intervention might facilitate more effective decision-making behaviour; nor of how it compares with other ways of doing things." (Cox, 1996. P358)

This particular observation is supported by the survey carried out for this thesis and discussed in Chapter 4. While Cox's observations were based mainly on the Australian experience, the survey carried out for this study examined a more European perspective. While it could not hope to be exhaustive, for reasons described in Chapter 4, the survey identified a substantial set of problems contributing to the failure of DSS technology to be taken up widely.

While the work outlined in Chapter 4 upholds the main findings of Cox's paper his conclusions are not supported. The research described here can be used to refute his claims and provide evidence that DSS, if developed within a user-centred design environment and focused on the decision process itself, can serve as valuable components in the technology transfer process.

Cox suggests three reasons why the use of DSS by farmers is not practicable:
they are based on a platform (computer) which few farmers currently use as a planning tool

- they frequently require monitoring data which it is unrealistic to expect the farmer to collate

- the design and presentation of DSS are sufficiently complex to require considerable technical support before one can operate them effectively (Cox, 1996 pp.360)

The first point, lack of computer use, has been shown by surveys discussed in Chapter 3, to be increasingly untrue of UK crop producers. Existing UK farmers are becoming more computer literate, as argued in Section 4.2.1, the next generation have grown up with them and larger farm units in particular have been shown to be regular users. Furthermore a recent call for volunteers to test an early version of the DESSAC DSS software generated a greater than expected percentage of responses from small producers (0-300 ha). While current thinking would suggest this group would be far less interested in computer-based decision support than the larger enterprises, there were slightly more returns from them than from the 300-600 ha sector (eight responses to five). One explanation for this behaviour is that the smaller, more forward thinking, producer is keen to evaluate technology which may be valuable in the fight to reduce costs and stay in business. The absence of a computer culture cannot therefore be used as an argument against the potential of DSS as a technology transfer mechanism.

On the second point, while research described in this document completely supports Cox’s finding that many existing models require obscure and unobtainable monitoring data, this does not have to be the case for future models. Taking weather data as the most common example, Section 4.2.3 suggests that many farmers and consultants collect minimum and maximum temperatures and local rainfall figures. That it is possible to develop useful models, which only require this data as input, is demonstrated by the disease and growth models developed for the DESSAC Wheat Disease Manager. It is also true, as argued in Section 4.2.3, that weather information of some complexity, electronically recorded and digitally stored, is slowly becoming more widely available (as is monitoring for other inputs i.e. pest numbers). The recent funding of a Foresight Commission project (HiRESAME) concerned with the development of local and regional
weather data delivery mechanisms for agriculture, shows that the provision of this type of data is seen as a priority.

Although a comprehensive set of weather data is still unavailable to the average user, its absence cannot be considered a sufficient argument against the use of DSS within the industry. In a user-centred design approach, a model's requirements for monitoring inputs would be weighed against the existing ability of the user to provide them and the potential benefits a DSS based on that model might bring to the user. The outcome of the equation may vary e.g. a modification to the model, a case for the user to purchase additional monitoring equipment, or a serious re-think of the problem. In any event, the problem of users being faced with a DSS for which they do not have the necessary monitoring inputs would not arise.

The final point, that the design and presentation of DSS means that end-users require considerable technical support to operate them effectively, can be shown to be invalid in the context of a user-centred design approach. While the research reported within this thesis supports Cox's observation that most of the currently available DSS are complex and hard for the average farmer or consultant to use, it also provides evidence that this does not have to be the case.

In addition to providing documentation to support the use of Decision Support Systems within crop production, the material in this thesis can be used to demonstrate that a user-centred design (UCD) approach is important to the development of a usable and widely accepted product. The need for such evidence is particularly great in an industry where the historical emphasis is on spending grant funds on biology and not on software development. User-centred design is not without its costs and grant applicants and grant providers need to be persuaded that earmarking sufficient funds to support it is a worthwhile investment. In support of this argument, the thesis describes the reason for the development of 'soft' user-centred system development methods (Section 2.3.3) and proposes the UCD approach as a key component of a well-balanced methodology (Section 2.3.6). Evidence that a UCD-based methodology could have avoided the problems leading to the failure of previous DSS is presented (Section 4.3.1) as are
examples of 'success stories' i.e. products which are well used and which employed a broadly UCD approach in development (Section 4.3.2).

The contribution made to the technology transfer process in crop production is not just the evidence that DSS can be useful transfer mechanisms, or in providing arguments to persuade developers that a user-centred approach is an essential pre-requisite for a successful system. The specific nature of the system development process within crop production means that by itself this would not be enough to promote the development of usable systems. This thesis has shown that those responsible for DSS development are in need of specific guidance on the ways in which users can become involved in the development process and that the means they have at their disposal to do this are limited and variable. The main contributions of this document to the further improvement of the technology transfer process are therefore the development of a flexible and DSS-focused methodology for user involvement throughout the design lifecycle, and a method for identifying and collating user interface requirements and design solutions.

7.2.2 Contributions to Decision Support Science

There are a number of contributions which the research has made to existing DSS knowledge.

The thesis provides additional evidence of the potential for the technology in an area which has not received much attention in mainstream DSS research. A search of the BIDS citation database for the years 1983-1998 revealed 54 papers which could be described as relating to agricultural DSS, none of which were published in *Decision Support Systems*, the key journal for this discipline. Agricultural DSS seem to be discussed largely within agricultural journals, mostly in journals specific to the area covered by the DSS (e.g. *Pest Science*) and more regularly in the more technical journals e.g. *Agricultural Systems & Computing and Electronics in Agriculture*. By examining the ability of the technology to improve knowledge transfer in crop production, and the specific benefits it offers the industry, this thesis offers an insight into the broader applications of DSS. In addition, the project work contributing to this thesis provides a good source of case study material.
More specifically academic contributions to the science of DSS were made in Section 1.3 where the relationship between DSS and Management Information Systems was described and discussed.

This thesis offers a view of the connection between the two types of system which differs from those suggested by previous authors. It views MIS as component parts of a class of computer programs called decision support systems and offers a new definition of DSS themselves i.e. 'a computer-based system designed to help its user make more effective decisions by providing information in a way which actively supports the decision process'. The definition may perhaps also be seen as a contribution, although there are many others which claim to do the same, its primary function within the thesis however was to provide a boundary to the discussion.

In addition to the review of MIS and DSS, this thesis also examines the distinction between DSS and Expert Systems (ES), another class of computer software with which DSS are frequently confused. The thesis makes it clear that according to the definition proposed, a standard view of an ES differs from DSS in several important aspects (Section 1.3.3) most notably in its objective (to replicate/mimic expert performance).

The description of a continuum of support for the decision process described later (Section 1.3.3) is also a potentially useful contribution in that it illustrates the range of positions that a DSS can inhabit. It can be used to rank DSS in terms of the support they offer the decision process and the degree of control they take away from the decision-maker. The diagram can, and has been, used (in the context of the DESSAC project) to argue the case against a complete interpretation of data.

Finally the work presented within this document can be seen to provide another clear example of the need for a user-centred design approach to the development of DSS in general, as well as for crop production DSS. It has been shown that crop production shares many characteristics with production engineering and with medicine (Section 1.3.4). It may therefore be inferred that these sectors share many of the same problems, with DSS design and development, encountered in crop production (most notably a lack
of take-up). A list of contributing factors pointing to a need for a user-centred design approach may also be found.

Evidence that there is a large degree of common ground between sectors is provided by a number of review articles from medicine e.g. Pitty and Reeves (1995). In response to an observation that many programs were viewed with suspicion and not used, Pitty and Reeves provide the view that 'the overall application is more important than the sum of its parts and ... a broad requirements analysis that encompasses organisational change is required at the outset.' Reisman, in a comprehensive review of clinical DSS suggests that 'acceptance by physicians depends among other things on ease of use of the user interface'. A wider requirement for a more user-centred approach to DSS development is supported by a paper in Decision Support Systems (Angehrn & Jelassi, 1994). The function of this review article was to look to the past and future of the technology and in it the authors state that 'the reason for many DSS failures is related to the poor/inappropriate integration of these systems in their organisational context'. Clear evidence for the need for a more user-centred approach.

7.2.3 Contributions to Human Factors

As with DSS, the flow of contributions between this thesis and the study of Human Factors has been predominantly in the direction of the thesis. There are some areas however in which the work described here maybe considered to have contributed something new to the sum of Human Factors knowledge.

The most obvious contribution is the translation of an idea from Business Science into a form which extends the boundaries of Cognitive Task Analysis (CTA) into decision support and provides a simple mechanism for identifying user requirements for DSS. This thesis has made the case for a fundamental distinction between decision-making and other tasks, largely based on the work of Prof. Bay Arinze (Sections 2.5 & 5.4) and supported by experience within DESSAC and GRIME. The limitations of current CTA techniques with respect to Decision Support System development or to any other small scale development have also been discussed (Section 5.3.2.2). This thesis describes the form and reasoning behind the 'Decision Enquiry' or question approach (Section 5.4) and
provides a practical demonstration of its potential for use in requirements analysis and refinement, and for evaluation purposes (Section 5.6)

This thesis has also provided another example of the value of a user-centred design approach and of the dangers of failing to adequately address user and organisational aspects in design (e.g. Chapter 4). The DESSAC and HORIS projects are useful examples of the range of UCD approaches that can be adopted: from the large scale involvement of users throughout a long design life cycle in a complex and highly innovative project to the very simple and focused interaction with users during the quick development process for a new version of an existing system. While evidence of the value of more complex UCD process in DESSAC is still limited to favourable reports from laboratory trials and initial observations by users, the merit of adopting even a simple consultation process is amply demonstrated by the continuing success of the HORIS software, now in its third release.

The development of a simple and flexible DSS specific method for incorporating user input at all stages of the design, development and maintenance process may also be considered a contribution to the growing body of Human Factors tools. Its uniqueness lies in its focus on user questions making it applicable to a group of software systems which other methods do not quite address.

The application of the question approach to user interface requirements capture is an extension of the general question approach to requirements identification. The use of this method to identify and collate design solutions for generic requirements is however, as far as the author is aware, a novel approach. Its primary value is in its ability to expand and incorporate generic requirements from all types of DSS and to form the basis of a general resource. Collation and sharing of design solutions should add support to the drive for greater standardisation of user interface features.
Chapter 7

7.3 LOOKING AHEAD - DSS & TECHNOLOGY TRANSFER IN THE FUTURE

What is the future for DSS as a method for technology transfer in crop production? This section examines the range of possibilities facing the use of DSS as a technology transfer mechanism and looks briefly at other emerging methods.

Looking first at the future for DSS as a technology transfer tool and at the spectrum of possibilities. At one end DSS achieve their potential and at the other they fail. Figure 7.1 illustrates one view of this spectrum which contains a list of the factors, discussed at various points throughout this thesis, which might be considered to be important to the success/failure of the technology.

<table>
<thead>
<tr>
<th>Chances of DSS realising potential as Technology Transfer tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSS acknowledged as TT tools</td>
</tr>
<tr>
<td>UCD recommended/adopted</td>
</tr>
<tr>
<td>Funding available</td>
</tr>
<tr>
<td>Success of ‘platform’ systems</td>
</tr>
<tr>
<td>Success of integrated modelling tool</td>
</tr>
<tr>
<td>Education of end-users</td>
</tr>
</tbody>
</table>

Figure 7.1: Spectrum illustrating the chances of DSS realising their potential as a technology transfer mechanism

7.3.1 Positive view

At the positive end DSS are acknowledged to be useful tools and fund-holders are willing to see them as such, overriding previous considerations of ‘near-market’ or ‘pre-market’ to make funding available for their development. MAFF and the Levy Bodies support both model and DSS development through funding initiatives such as LINK. In recognition of the impact of a user-centred design approach demonstration of the ways in
which users will be included in development and evaluation is made a pre-requisite for funding.

On the modelling side the GRIME system (or one like it) facilitates the development of new and improved models. GRIME supports communication between biologists and biometricians in a way that has not previously been possible, this and the library function which enables models and part models to be freely exchanged, greatly speeds up the development process. In addition the new approach brings with it a change in the way that models are conceived and improvements in the science of modelling create a new generation of fully integrated models.

GRIME makes it possible to transform completed models into the optimised code required by a DSS. As a number of pre-built generic interface structures have been made available to designers through such mechanisms as the DESSAC Toolkit initiative, it is a relatively simple task to create new DSS modules.

Standardisation permits the raft of new and useful DSS which are thus made available to the crop production sector to be easily incorporated into one of the ‘platform’ systems (e.g. DESSAC or Morph). Thus negating the need for re-entry of data and providing a common set of navigation and interface mechanisms. As a consequences of the availability of a large number of DSS and related information systems, one or more ‘integrator’ programs are produced. These act as co-ordinators between DSS and crop/farm management systems and allow the user to check the knock-on effects of one action on other farm activities.

Finally an education program which prepares crop producers and consultants for the advent of DSS is instigated, ensuring that users understand the limitations and specific uses of the software they receive. The combination of education program and UCD approach brings the two ends of the science continuum, scientists and practitioners closer together and permits even greater levels of communication. The involvement of consultants in the design of DSS will improve the probability that the systems not only carry science outwards but also actively encourage good practice. The consultants knowledge of the decision process and the difficulties in improving techniques being
used to temper the scientists enthusiasm for a pure approach. The shared use of systems between crop producer and consultant and the graphic demonstration of the consequences of applying decision options should also increase the power of communication between these parties.

Figure 7.2 illustrates the flow of scientific knowledge to the industry mediated by models embedded in DSS and the flow of information back to the research institutes. An increase in understanding of the performance of models 'in the field' provided by feedback from consultants/crop producers has the added benefit of increasing the ability of scientists to generate more robust versions.

7.3.2 Negative view

At the opposite end of the spectrum a failure in any one of the dimensions listed in Figure 7.1 would have serious consequences for the future of DSS in crop production and, in the view of this thesis, for the whole technology transfer process. If funding bodies fail to be convinced of the potential of DSS then the whole chain falls apart. Pure science models may continue to be generated but, as discussed elsewhere (e.g. Cox. 1996), these are unsuitable for use in the field. Interest in modelling may dwindle as a result and tools such as GRIME cease to be of interest. A failure to obtain funding for DSS will also lead
to the failure of the platform technologies, whose future success is reliant on the availability of a range of DSS.

If models and DSS continue to be funded but no attention is paid to UCD then it is likely that the number of ‘failures’ will increase. Eventually this will knock confidence in the technology and funding may eventually cease.

If the education of end-users does not take place then, while DSS may still succeed in the short term, there is a real danger that the systems will be misunderstood and misused. The result of misuse, and several well-publicised crop failures as a consequence, could be a set back in confidence (and therefore funding) resulting in a similar situation to that generated by a lack of initial faith in the technology. The faster that DSS appear on the market the greater the need for a mass program of education becomes and therefore seeming success in one area could result in a later crisis if this area is neglected.

Finally, while the failure of GRIME (or of the advent of a modelling tool/delivery system) will not prevent DSS from realising their potential as a technology transfer mechanism, its success, or that of a similar system would greatly facilitate it. The failure to create a simple modelling tool which delivers DSS ready code will deny the chance of a ‘fast-track’ to DSS production. Fast delivery may be critical to ensure continued interest by crop producers and consultants.

7.3.3 Educated guess

Having painted both the rosy and the bleak pictures for the future of DSS as a technology transfer mechanism, it may be appropriate to make an educated guess as to the direction the actual future will take. The following scenario is based on an understanding of the industry gained as a result of work for this thesis.

There is no escaping the fact that UK crop producers need better access to scientific developments in order to stay competitive. It is also obvious that there is little else which offers the same type of immediate and flexible access to knowledge at the same low cost as a DSS. It is also true that similar systems appear to be providing significant benefits to
our European (Proplant) and Scandinavian (PC Plant Protection) neighbours. The chances are therefore that models and DSS will continue to be funded, to a certain extent, on the basis of their potential as a technology transfer mechanism.

It is also likely that the pressure to reduce inputs on crops will increase rather than decrease in the coming years. As DSS, particularly those with some form of 'decision model' to support optimisation, are particularly good at supporting the best use of permitted pesticides, their value is likely to increase. A recent exercise aimed at estimating the value of decision support models to the brassica and top fruit industries concluded that they would more than justify their costs (Lucey et al., 1997). The ability of a DSS to provide a means of justifying applications makes them even more useful in a world which demands increasing levels of 'traceability'.

On the other hand the lack of obvious success to date, and a scarcity of resources, is making both Levy Bodies and MAFF fairly cautious. Funding may continue to flow but more slowly than on previous occasions until such time as projects currently under development e.g. DESSAC or Morph start to show benefits. In the case of DESSAC, the funding agencies (MAFF, BBSRC and HGCA) have spent such a high percentage of their available resources on the project to date and, because of its five year duration, have yet to see any signs that their investment was well made. Loud complaints have also been heard from those uninvolved in the project who either do not understand its purpose, feel threatened by it, or are more interested in funding for other topics. These factors naturally make funders nervous and unwilling to commit more public money until concrete evidence of success can be provided.

The consequences of this 'slow down' in funding are not clear. There is however a danger that, given the time it takes to get a usable model prepared and inserted into a DSS platform, an absence of funding for a few years will jeopardise the position of DSS as a technology transfer mechanism. If DESSAC is a success then users will soon start demanding additional modules, a failure to provide them quickly enough may result in a loss of interest and enthusiasm. On a more positive note, if the results of the initial years trials for the DESSAC system are positive (season 1998-1999) then there may only be a...
short loss of momentum. Consultants and crop producers may also be more patient and forgiving of delays in production than expected, particularly if they are not alienated from the production process.

Gaining acceptance for the need for User-centred Design is in many ways more problematic. While many developers appear to pay lip-service to the notion of usability they are less willing to part with funds from existing budgets to facilitate the inclusion of users in the design process. Funding bodies themselves are unaccustomed to providing, or justifying the provision of, additional funds to allow this process to take place (although the recent funding of the DESSAC validation process, a 2.5 year exercise, shows that some authorities are willing to take action). Pressure from agencies such as HUSAT to include a realistic sum of funds for the user aspect in project proposals is often viewed with some suspicion. It is seen more as a mechanism to increase HUSAT's share of the budget rather than a genuine attempt to ensure the final usability of the product. On the author's part, it is also true that pressure to reduce the demand for additional spending, coupled with the desire to ensure some user interaction, results in a proposal which is less than ideal either from a UCD or from a project management perspective.

It is possible that, if sufficient effort can be found for lobbying and demonstrating the value of a user-centred design approach, the funding agencies will be more willing to accept bids for support in this area. More importantly they might be persuaded to reject proposals which do not show evidence of giving thought to this critical component (in much the same way that they now require proposers to show evidence of a dissemination path).

As discussed in previous chapters however, it is not enough to push developers to consider UCD if they are unable to lay their hands on the methods and tools with which to carry it out. The methods proposed within this thesis may be the answer. If this should prove to be the case then its widespread dissemination, in a suitable format should be sufficient to ensure that all developers have the necessary knowledge to adopt a UCD approach. This may also serve to reduce the perceived pressure on them to share their
precious resources with an outside agency, as it will be completely in their hands as to whether they employ additional 'experts' for some of the user interaction tasks.

If funding does not dry up completely and the initial warm response to the DESSAC system is continued throughout the coming two seasons trials then it is highly likely that this particular platform project will be a success. (The author has insufficient data to comment on the likely success of the Morph system). Comments from trial users lead the author to believe that the time for this technology is right, the computer systems are adequate and the need for additional 'competitive edge' knowledge is apparent. The high degree of user involvement throughout the development of this system has lead to a design which meets the majority of the requirements specified by users22.

The potential for a successful modelling system which supplies code directly to one of the platforms is also quite high. As the GRIME system is being developed with the Horticultural Research International at Wellesbourne, the group which is also responsible for Morph, it is quite likely to be promoted for use within that institute. If this happens and is successful the large number of users it will have initially will undoubtedly increase its chances of being taken up by modellers in other institutes.

Finally the education of end-users on the use of models: an area, which like several others above, relies largely on the foresight and inclination of the funding bodies to make it happen. The materials and format for bringing these ideas to users already exists (see TIM in Chapter 3) and it would not take a great deal of organisation to bring it to life. Given the continuing interest in promoting the use of models it is the author's view that this task will be accomplished in some form or another.

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22 It is very satisfying to be able to respond positively, as the author has on many occasions, when individuals or members of an audience declare that the system needs to be able to do this or that before it is of use to them.
7.3.4 Other emerging technologies

Since the start of this thesis technology and in particular the Internet has grown beyond most people's expectations of it. In the crop production area in particular, where the surveys (reported in Chapter 3) on the increasing use of computer technology were met with scepticism until very recently. In 1995, the author presented a view of the type of system that would meet the user requirements gathered in the first phase of the DESSAC user requirements analysis. In this futuristic scenario new data relating to varieties was emailed out to users (in response to complaints that they received the data too late to be of use in that season) and farmers and consultants were able to access local weather and other information via the Internet (in response to a lack of local data). To say that the comments the view received were scathing would be to play down the response. At that time, a group of high profile farmers, distributors, educationalists and consultants could not conceive of the industry using technology in this way. A mere five years on and virtually all of them use email as a matter of course, and most make some use of the wealth of farming-related Internet information that has emerged since that time e.g. Farming-on-Line, HGCA pages, Agronomy-on-Line or the Rural Information Network.

Given the dramatic changes in technology is it possible that other mechanisms will prove to be easier and more cost effective than Decision Support Systems? The answer depends on the type of knowledge that the industry needs better access to. The strength of model-based Decision Support Systems is in their ability to support the user in looking both into the past and the future, in conducting 'what if' analyses, manipulating key variables and examining the impact they have on outcome. If this type of support is the main priority for the user then there appears to be no other option to model-based DSS. The way in which these systems are employed may however vary considerably in the future.

The increased use of the internet and other networks may however lead to other solutions than a DSS on every machine. Observations from recent visits to farm and consultant premises suggest a trend for farmers to 'network' home and office buildings and there has been talk of consultants setting up a local network to link their offices to their clients.
(fuelled by recent extensions and price-reductions to the home-office services offered by British Telecom). The main objective of this networking activity is to provide common access to information. It is not inconceivable therefore that DSS could also be used in this way, the consultant providing access to a suite of DSS or to the results of running DSS on a farm’s data. Farmer groups could share DSS in the way that they currently share major items of farm machinery. Other consultants or groups could offer bureau services based on their access to DSS. The current speed of the internet precludes much useful interaction with web-based DSS but the future may remove this restriction. In this case research institutes could licence access to their sites and to DSS resident on them.

Methods for delivering non-interactive information (e.g. market information, weather data, variety trials results, disease and pest forecasts, encyclopaedic information), essential for the decision-making process and for feeding into DSS, are changing rapidly. Static non-interactive data, such as the material found in reference books and encyclopaedias is already well established in digital format in many sectors and is becoming more common in crop production (e.g. HORIS, MORIS, DESSAC encyclopaedia). CD is the most common delivery method at present but no doubt higher capacity and faster formats will soon become available. The Internet is also used to deliver this type of information e.g. Agronomy on Line, HGCA pages. Dynamic information such as market and weather information is particularly suitable for Internet dissemination and is already used for such by agencies such as HGCA and the Met Office. The future is likely to see rapid expansion of these services and a growth in specialist groups sharing information. A particular area which already shows signs of developing in this direction is the shared use of weather monitoring data, the David Martin Consultancy group have been developing a network of linked weather monitors in the East of England for several years (personal communication) and fruit growers in the South are reported to be doing the same (Laurenson & Cross, 1997).

7.4 OUTSTANDING RESEARCH QUESTIONS

The aim of this section is to explore the directions that future studies would need to take if the limitations of the current research are to be addressed. The breadth of this study
and the limitations on time mean that inevitably there are many areas in which more work could, and should, be done. This section will attempt to limit suggestions to areas of major interest although there are many other minor detours which the author, given time and money, would quite happily make. Each research area is discussed under its own heading below.

### 7.4.1 Testing of UCD method

The most obvious area for further research is the proposed UCD method for DSS development. While based on previous research and composed of many parts well tested in experience, it lacks the type of scientific testing which would make it possible to ‘push’ its use in the industry. Unfortunately it is not the type of product which one can take into the laboratory and apply a standard experimental design to, it has to be used in anger, by real practitioners before its real value can be assessed. The only real method of doing this is to propose its use within the context of several DSS development projects, ideally projects of differing sizes and scope. To be realistic the chances of one organisation achieving this in the short term are not good, proposal success being more of an art than a science. It may be more practical, if more rapid feedback is required, to work through funding bodies and offer the method to newly funded DSS consortia in return for feedback on its use.

### 7.4.2 Development of interface requirements and design tool

The idea of using generic questions to gather together and present DSS interface design solutions is developed in Chapter 6. Its scope however is limited largely to questions emerging from the study of fungicide applications on arable crops. Although the requirements for horticultural systems are shown to be similar, differences in approach were also indicated and these have not been addressed in this thesis. Further research is needed to expand the list of interface questions to include those from other produce sectors. This can only be achieved by carrying out the same types of user requirements analysis conducted in the projects described in Chapter 3, although some retrospective re-analysis of existing horticultural data may also generate results. It may be possible to
approach the problem in isolation of a product development project i.e. to identify and interview representative samples from each distinct user group in each sector for each type of problem. Experience however suggests that users are more willing to give time and thought to this type of issue if it is grounded in a practical problem. It is therefore more likely that the additional data will arise gradually as a result of data from individual DSS projects.

7.4.3 Communication within the crop production industry

This thesis has, of necessity, focused on communication between scientific institutes and those at the hard end of crop production i.e. farmers and consultants. There are however considerably more parties involved in the process of crop production, as has been suggested in Chapter 1, whose requirements have not been touched on by this thesis. Good communication between those involved in the supply chain for arable and fresh produce is more important now than it has ever been before. In some areas it is now possible to identify, at the retail point, the producer and the field in which a crop has been produced as well as all the nutritional and pesticide treatments to which it has been subjected. New products are emerging to facilitate this communication process (e.g. FoodTrak™) but more research is required into the actual requirements for this type of technology. In particular how DSS may need to develop to fit into the needs of this expanded chain.

It would also be useful to look more closely at the links between scientists and end-users, building on the observations made within this thesis, to explore ways in which communication can be improved without detracting from the main function of either group.

7.4.4 User education on model use

The development of a mechanism for educating end-users on the uses and limitations of models was described in Section 3.6. The continuing and increasingly important need for such a method (as argued in Section 7.3.3) suggests that further work in this area is also required. A proposal for a set of workshops has already been developed. The suggestion is that sets of workshops are conducted over a two year period (along the lines
set out in Section 3.6), with time to re-evaluate and make changes between each set. The workshops will be tailored to provide immediate impact to each of the main commodity groups. At the end of the two year period the materials will be collated and made available in the form of an on-line tutorial, accessible via the Internet or on disc. The administration of questionnaires before and after each workshop session will be used to determine the effectiveness of the material. It is proposed that a random sampling of farmers and consultants be used to assess the more general impact of the educational material over a number of years.

7.4.5 Encouraging DSS developers to adopt a UCD approach

The need to encourage DSS developers to adopt a user-centred design approach was stressed in the previous section. While methods have been proposed to support them in this activity the means by which they might be persuaded to use them have not really been addressed. Further research is required to examine the ways in which developers can, most effectively, be encouraged to adopt this approach. A number of mechanisms might be proposed and tested. Applying pressure from funding bodies has already been mentioned. Another possibility is the development of a ‘How to..’ guide for DSS development in this sector, similar to the general usability text funded by the DTI in the early 1990’s (Preece, 1993) or the one published by HMSO and targeted at the best use of expert systems (Dale et al., 1991). The DSS guide might contain general information on the uses of DSS and the best types of application as well as the practical guidance on development methods and interface design described in Chapters 5 and 6. The availability of this guide via the internet would allow regular updates and a mechanism for exchanging new design ideas would do much to advance the level of knowledge in this area.

7.4.6 The use/non-use of DSS

While some effort has been expended on examining the reasons for success and failure of DSS projects and the hypothesis that a UCD approach would do much to improve matters, it has not been possible to test this hypothesis with any degree of scientific rigour. Part of the problem has been the difficulty in obtaining information about
systems. As discussed in Chapter 4 they are not often described in academic journals and when they are the information relates to specific problems addressed in development and rarely to performance in the field. The failure of most to achieve reasonable levels of use makes it hard to identify and interview users, the developing institutes being somewhat chary of allowing access to their subscriber lists. The failures for the most part disappear without trace and the successes are few in number but highly visible.

If DSS technology does take off then it may at last be possible to approach users directly for their views on the usability and utility of products and to combine this with information about the level of user involvement in a project and its success over a number of years. It is only by obtaining this type of data that the real value of a UCD approach can be demonstrated to funding agencies and developers alike.

7.5 CONCLUDING REMARKS

There are several academic contributions made by this thesis to the study of technology transfer in crop-production and to DSS and Human Factors; the most important ones are outlined in Section 7.2. These contributions have been submitted to academic journals, and more will be in the near future. However, five years after the start of this research the problem which prompted this research is still unresolved. While funds are still being allocated to DSS development there is a limited awareness among developers of the importance of involving users in the design process and little understanding of the ways in which a user-centred design approach might be implemented. This thesis has made a start by providing evidence of the importance of UCD to DSS success and describing a simple method which can be used within projects of any size and budget. Academic dissemination of this information however, while potentially valuable from a career perspective, will not resolve the problem.

Practical problems require practical solutions and there is an urgent need to translate the material contained within this document into a more accessible form. The user-centred design approach has to be institutionalised in DSS development teams if the next generation of crop-production DSS is to meet with greater success than the last.
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References


References


References


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References


References


References


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References


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<tr>
<th>Acronym</th>
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<td>ADAS</td>
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</tr>
<tr>
<td>APRC</td>
<td>Apple and Pear Research Council</td>
</tr>
<tr>
<td>ARC</td>
<td>Agricultural Research Council</td>
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<tr>
<td>BBSRC</td>
<td>Biotechnology and Biological Sciences Research Council</td>
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<td>CSL</td>
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<tr>
<td>CTA</td>
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<tr>
<td>DESSAC</td>
<td>Decision Support System for Arable Crops</td>
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<td>DOOS</td>
<td>Designing Object Oriented Software</td>
</tr>
<tr>
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<td>Dynamic Systems Development Method</td>
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<tr>
<td>ES</td>
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<td>ETHICS</td>
<td>Effective Technical and Human Implementation of Computer Based Systems</td>
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</tr>
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</tr>
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<td>HGCA</td>
<td>Home Grown Cereals Authority</td>
</tr>
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</tr>
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<td>Jackson System Design</td>
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<tr>
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<td>National Institute of Agricultural Botany</td>
</tr>
<tr>
<td>OMT</td>
<td>Object Modelling Technique</td>
</tr>
<tr>
<td>OO</td>
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</tr>
<tr>
<td>OOA/OOD</td>
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<td>OR</td>
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<td>RAD</td>
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<td>Skilled With Advanced Tools</td>
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<td>Yourdon Structured Method</td>
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Bridging the Gap:
User Centred Design and Support Methods for Decision Support Systems in Crop Production

By

Caroline Parker

APPENDICES

A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of PhD of
Loughborough University

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APPENDIX D:       DESSAC SECOND PHASE USER REQUIREMENTS SURVEY
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GRIME User Requirements Survey Report


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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G.R.I.M.E

'Results of the First Phase User Requirements Analysis'

- 10th May 1994 -

Caroline Parker
HUSAT Research Institute
The Elms, Elms Grove
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1.0 INTRODUCTION

This report details the work carried out by HUSAT during the first months of the GRIME project (Growers & Researchers Integrated Modelling Environment) which is concerned with the integration and dissemination of prediction and forecasting models. The aim of this early work was to identify the user requirements of two of the target user populations, Brassica growers and advisors/consultants as part of the 'User centred design' approach adopted by the project.

'User centred design' involves making the user the focus of activity, taking their needs into account throughout the design process, thereby avoiding the expensive failures and usability problems associated with technology centred techniques. The early part of this procedure is concerned with collecting and synthesising information about users needs and capabilities. This information can then be used to develop a conceptual model of the system, a first stage design and can also act as a useful reference when additional questions about user needs arise during the lifetime of the project.

GRIME has three main user groups 'growers', 'scientists' and 'advisors/consultants'. The needs of the scientists, focused as they are on the development of models rather than their utilisation, are sufficiently different to require a separate study which will be reported elsewhere. This report then is concerned with the needs and requirements of growers and advisors. Prior to developing prediction and forecasting systems for their use, the user centred design philosophy suggests that certain knowledge about the domain is collected, ie:

- who will use the system
- what will they use it for
- the work context and environment in which it will be used
- what is technically and logistically feasible (DTI, 1990)

These, placed in the current context, can be translated into the following questions:

A Is there a need for prediction/forecasting models in the grower/advisor population, or are the existing sources of information adequate?
   - Do all growers and advisors have a requirement for such systems?
   - If there is a requirement, how strong is it?

B Do the technological and informational components required for prediction/forecasting models exist, and if not, is it likely that these will become available in the near future?
   - Do growers/advisors have access to suitable computer systems and to the meteorological data utilised by forecasting models?
   - If not would they be willing to gain access given suitable incentives?

C Where will prediction/forecasting models be of most use?
   - Which particular pests, diseases and nutritional requirements do growers/advisors consider to be most important.

Results of initial user requirements analysis
D What constraints do the users operate within?
- What are the goals of the users and their companies?
- What are their markets and what pressures do these exert?
- Are there any other relevant external influences?
- What changes are currently taking place or likely to take place in the near future?

E What type of interface requirements should be taken into consideration when building the system?
- Who are the potential users?
- Do they have computer skills?
- What other tasks will they be carrying out?
- What other facilities might be built in to ensure that the system is used?

Section 2 of this document briefly describes the methods used to elicit answers to the above questions. Sections 3 and 4 describe the results of a postal questionnaire and interview sessions, and Section 5 summarises the key findings. This document should be seen as an initial collation of user requirements which will be revised throughout the project as new information is gathered.
2.0 METHOD

The first three questions posed in the previous section, 'is there a need for these systems in the user population', 'is the technological and informational underpinning in place' and 'which are the key areas for prediction and forecasting systems' are factual, largely requiring yes/no answers. As such they were capable of being incorporated into a postal questionnaire which has the advantage of being cheap, and capable of eliciting responses from a larger group of people than would otherwise be possible. However the method lacks the 'richness' of data associated with interview techniques and so the same questions were also asked of a sample of growers and advisors during face to face interviews to put 'flesh on the bones' or to provide useful case studies.

The final two questions, concerning the characteristics of the users, their tasks and the constraints under which they operate, are more complex and not easily posed in a paper format. Knowledge about these issues was obtained both from background reading and from structured interviews with a sample of the user population.

2.1 Early interviews

Three preliminary interviews were carried out in December 1993 with the aim of clarifying the problem area ie identifying areas of interest, useful questions for use in later interviews and the type of people involved in the growing process. While these interviews were largely unstructured, a number of prepared questions were pursued. The questions formulated from this process were then divided according to their suitability for a postal questionnaire or face to face interview.

2.2 Postal Questionnaire

The questionnaires were initially sent out in small batches as new contacts were identified, e.g. the Horticultural advisor of the NFU, Karen Renner, agreed to distribute some at a meeting of the Horticulture group, and David Wurr of HRI Wellesbourne provided a list of growers and advisers. This method of dissemination proved to be very time consuming, and so the provision of a suitable HDC list of around 170 Brassica growers by Rosemary Collier of HRI Kirton and Mary Bosely of HDC was greatly appreciated! Approximately 200 questionnaires were distributed in total.

The final mailing list was almost exclusively composed of growers, providing little data on the other main user group, advisors and consultants. To redress the balance a further mailing is currently taking place.

2.3 Interviews

Fifteen face to face interviews have taken place to date. Four of the interviewees were advisors (2 ADAS, 2 independent), and the rest were growers. Most of the sample were from Lincolnshire, 2 were from Cambridgeshire, 2 from Norfolk, 2 from Lancashire and 1 from Derbyshire. All sizes of grower company are represented, ie 2 Co-ops, 2 large independent growers, several medium sized growers and several small/market garden size companies. The participants have either been technical advisors, crop managers or managing directors/owners and manage crops of broccoli, cauliflower, Brussels sprouts, cabbage or turnips. Time has also been spent talking to a couple of the 'people who do the typing in' at the smaller growers, ie wives.
3.0 POSTAL QUESTIONNAIRE - SUMMARY OF RESULTS

3.1 Occupation of sample
Approximately 200 questionnaires were distributed to Brassica growers during January and February 1994. A total of 78 people replied, which can be considered a good response for this type of survey. Seventy-two of the 78 respondents described themselves as 'growers', 1 as a consultant the rest as 'commercial', 'co-op' or 'consortia'. Although the questionnaires were anonymously returned an examination of the legible postmarks showed that most key growing areas were represented, figure 1 below illustrates the pattern of returns.

![Figure 1: Showing distribution of 61 legible postmarks](image)

3.2 Computer usage
Two thirds of those who responded own a computer, most of which are IBM or IBM clones (83% of all computers). Of the 48 systems with known operating systems 70% were DOS based machines and 60% were also capable of running Windows (see Fig.1). The majority of computers have colour screens (85%), hard discs (96%) and a mouse (76%). Of the 46 who answered the printer question, the majority (34) use dot matrix printers, a further 6, inkjet machines and 3, laser printers.

<table>
<thead>
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<th>Frequency Distribution for O/S</th>
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<tr>
<td>Count</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>CP/M</td>
</tr>
<tr>
<td>Dos</td>
</tr>
<tr>
<td>Windows</td>
</tr>
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<td>Windows/Dos</td>
</tr>
<tr>
<td>Unknown</td>
</tr>
<tr>
<td>Total</td>
</tr>
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![Pie Chart for O/S](image)

Figure 2: Showing frequency distribution of operating systems used by respondents.

Results of initial user requirements analysis
The questionnaire asked people what things they used their computer for based on a tick list of 16 items. The most common uses were accounting (86%), word processing (82%), farm/field records (59%), stock records (57%), management (45%) and presentation materials (30%). Approximately a quarter of respondents also use their computers for staff/labour planning (24.5%), general crop scheduling (22%) and planting (24.5%). Other uses include spray planning (14%), client databases (12%), modelling (12%) and crop maturity prediction (10%).

Management Software
Of the 24 people who answered the question about management software 15 said they used proprietary software e.g. 'Optomix', 'Farmplan' and 8 their own 'customised' software or spreadsheets.

Who are the users?
Almost half of the 33 responding to this question said they used the software themselves (45%), 24% said others used it and 24% that they and others used the system. Of the 'others' involved 12% said senior staff and secretaries and another 6% office staff.

3.3 Non-computer users
Twelve of the 26 people who said they did not currently own a computer are thinking of getting one in the future for management purposes, interest, integration with other technology or in response to parent company demands. Five of the 26 said they would not be getting one; financial or 'no justification' were the reasons given. Nine people didn't answer this question.

Eighty-one percent of the people who do not currently own computers said they would find paper based forecasts useful.
3.4 Meteorological Data

Almost 2/3 of the sample population make use of meteorological data (64%); 76% of those who do collect their own data and 44% use the local Meteorological station.

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<td>81</td>
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<tr>
<td>Min/max</td>
<td>15</td>
<td>39</td>
</tr>
<tr>
<td>Windspeed</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>Temp</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Solar radiation</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Wind direction</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Pressure</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Soil temp</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Solar weather action (PCWS)</td>
<td>1</td>
<td>2</td>
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</tr>
<tr>
<td>Sun &amp; shade</td>
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Table 1: Showing the types of data collected by respondents.

The most common type of data collected by respondents is rainfall (81%) and min/max temperatures (39%); however windspeed and daily temperature are gathered by a significant minority (21% and 18% respectively). Other measure such as air pressure, wind-direction, solar radiation, solar weather action, sun/shade or moon cycles are gathered by less than 5% of those responding.

<table>
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</tr>
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<tr>
<td>Frost</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Sunshine hours</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Solar radiation</td>
<td>1</td>
<td>4</td>
</tr>
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</table>

Table 2: Showing types of data collected from the met. office.

Of those who use Met Station information 54% said they used rainfall data, 40% temperature (including min/max temperature) and 36% windspeed data; less than 5% reported using wind direction, frost, sunshine hours or solar radiation.

Eleven out of the 14 people who answered the question said that they would consider getting their own weather station. Some of the circumstances considered necessary to the purchase were 'if the cost could be justified', 'they were automatic' or if 'Met Station data was unavailable'.

Ten out of the 22 people who said they used meteorological data also said they were happy to adjust it to local conditions, 3 were not always happy to do so; 9 did not answer the question. Ninety-five percent of the 61 people who answered the question said they made use of weather forecasts.
3.5 Decision support tools

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<td>78.21</td>
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<tr>
<td>Diseases</td>
<td>52</td>
<td>66.67</td>
</tr>
<tr>
<td>Nutrition</td>
<td>40</td>
<td>51.28</td>
</tr>
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</table>

Table 3: Showing the type of decision support tools respondents suggested they would find useful.

**General:** Over three quarters of the sample (78%) indicated that they would find useful some form of prediction or forecasting system concerned with pests, two thirds said they would like one concerned with diseases (67%) and around a half (51%) would like one concerned with nutrition. Other decision support systems received less support with around a third of respondents looking for support in predicting crop readiness (33%) and planning irrigation requirements (33%) and around a quarter who felt help making crop scheduling and crop spacing decisions would be useful (26% and 28% respectively).

**Pests:** When asked which pest forecasts would be most useful 57% out of the 61 who responded to the question said cabbage root fly, a further 18% carrot root fly; 49% Brassica related aphids such as mealy and cabbage aphid; 11.5% caterpillars e.g., diamond back moth and small white butterfly. Forecasting systems concerned with cutworm, pollen beetle and slugs were requested by less than 5% of the respondents.

**Diseases:** A wide variety of disease forecasting systems were requested by the 52 people who felt this type of decision support system would be useful (see Appendix A). Respondents appear to want systems to forecast the appearance of spot producing diseases of which the most important appear to be Alternaria (15%), Ring Spot (11.5%) and White Blister (11.5%). Systems for forecasting Mildews also seem to be required, most of the requests were not specified but 7% wanted Downy Mildew and 2% Powdery Mildew. A forecasting system for Botrytis was requested by 13% of those responding.

**Minerals:** Of the 40 people who requested decision support tools concerned with minerals 32 (80%) were interested in Nitrogen, 32% Phosphate and Potassium, 27.5% Magnesium, 10% Calcium and 5% Sulphur. Trace elements were also seen as important with 22.5% interested in Manganese, 10% in Boron and 5% in Copper. No-one expressed a specific interest in Iron or Molybdenum.

3.6 Sources of information
Seventy two people provided details about their current sources of information. A wide variety of sources were quoted (see Appendix A) the most frequent of which were ADAS (46%) private consultants (21%), chemical companies (18%), in-house expertise and experience (15%), HDC (13%) and HRI (11%).

Results of initial user requirements analysis
4.0 INTERVIEW DATA - SUMMARY OF RESULTS

The following section attempts to identify the main players in Brassica production, to describe their roles and responsibilities, the main goals of the industry and of individuals, based on the results of the 15 face to face interviews described in Section 2.0.

4.1 ROLES

Viewing the process from an information/product flow perspective there appears to be three main areas of activity, the core as far as the focus of this project is concerned is the area in which the growing and initial preparation of the product takes place and the key roles within it are that of the Nursery, the Grower, the Co-op and the Packer. In the 'real world' a company may carry out more than one of these roles.

The roles which feed into the growing/preparation process whilst remaining outside of it are those of Research, Advisor, Seedsman, Chemical Supplier and Fertiliser Supplier; again several of which may be combined in an existing company.

The third area is concerned with the final destination of the product, the markets, and these have been identified as Retail, Wholesale, Processor and Supermarket. These roles are unlikely to be combined.

Results of initial user requirements analysis
- 8 -
The part each of the above roles plays in the Brassica production process, in particular the information they provide and to whom, is summarised below:

4.1.1 Stage 1 roles

Seedsman
Provides seeds to Nurseries, Growers and Co-ops.
Provides information on varieties to Nurseries, Growers and Co-ops, Research, Advisors.

Chemical Companies
Provide chemicals to Nurseries, growers, Co-ops.
Provides information on chemicals to Nurseries, Growers and Co-ops, Research, Advisors.
Provides information on pests and diseases to Nurseries, Growers and Co-ops.
They do some field walking/pest, disease identification as part of sales incentive, although this may be declining.

Fertiliser Companies
Provide fertilisers to Nurseries, growers, Co-ops.
Provide soil testing service to Nurseries, growers, Co-ops.

Advisors
ADAS, Private consultants
Both tailor service to client needs, individuals have crop/lifecycle specialities. Many larger companies keep them on a retainer basis and use when needed.
Provide advice on all aspects of the business; feasibility, scheduling (may produce full year plan), crop care, pests/diseases, production lines, marketing, etc.
Often do field walking for larger growers and co-ops.

Research
HRI/ADAS do bulk of vegetable research. They bid for funds from MAFF & HDC.
MAFF funds pure research. HDC funds 'near market' research, supported by industry via a levy system (up to .5% of gross turnover).
Variety information: NIAB do regular variety trials; Seedsmen provide some research; Most growers/co-ops do their own trials each year.

4.1.2 Stage 2
As mentioned earlier there is often a large overlap between these roles in the real world, some companies run nurseries and grow, some grow and pack, some are independent, some pure Co-op, some are a mix of independent and Co-op. Each business seems to be individual. All take information from wherever they can find it, depending on the price.

Nurseries
Supply young plants to growers and co-ops.

Growers
They come in all shapes and sizes. The smaller grower/market gardener is felt by many to be a dying breed, larger more market oriented companies can produce more goods, at a cheaper price and therefore get the best markets. Smaller growers more likely to do their own plant raising and may pack for local retail consumption or supply packers. Some supply wholesalers. Some are part of Co-ops and may give some or all of the control over the growing process to them. Larger growers may also belong to co-ops. If not they seem to be more likely to buy in plants but to pack themselves.

Co-ops
A group of growers organised by a central body. Each grower has their own relationship with the Co-op and allow it varying degrees of control over the crop lifecycle. The Co-op is usually responsible for providing seedlings, finding markets, scheduling crops and harvesting, packing and delivery. Growers tell them what they’d like to grow and how much, the Co-op adjusts this according to the market demand. Co-ops sell mainly to supermarkets, wholesale and processors.

Packers
Deal direct with supermarkets, retailers. Independent packers specialise in certain products, may grow some & buy in other vegetables to suit needs e.g. stewpacks.

4.1.3 Stage 3 Markets

Retail
Local shops. Supplied mostly by smaller growers and wholesalers. Good price for small quantities, demand high quality but do not have not the strict requirements of supermarkets.

Wholesalers
Supplied mostly by larger growers and co-ops. Bulk buys for lower prices; less particular about size/colour/shape than supermarkets & not quite as demanding on quality.

Supermarkets
Main force behind changes in industry. Deal only with large companies (Co-ops/growers/packers) and often have exclusive contracts ie grower is not allowed to sell to rival supermarket. Demand best quality, specific and uniform size at cheapest price but buy in huge volume.

Processors
Canners, freezers, ready meal producers. They are less particular about size/shape - have different requirements for different products. Some quality aspects not so important for some products. Not seen as best source of revenue by most but useful to send 'non regulation' crops to.
The following section provides a rough first stage description of the main tasks that have to be carried out in stage 2 of the Brassica production process.

The allocation of tasks to the areas shown in figure 5 is not fixed and exists simply to identify the areas in which the project should focus its attention. The field and glasshouse task areas are key to the project because they are the areas in which modelling/prediction systems will be of most use. Marketing is also an area of interest because fore-knowledge of potential peaks and troughs in production is an important component of this task.
4.3 GOALS

The following diagram (Fig 7) is an initial description of the main goals and sub-goals to be achieved by the grower in order to be able to sell all of his/her product at the best price obtainable. The goals seem to easily decompose into two main areas, crop based goals and market based goals and for the purposes of this report the focus has been placed on the crop based goals.

The person responsible for the production of the crop has 5 main targets to meet: to produce a high yield and therefore get the best return on the original investment; to ensure continuity of supply and thus avoid having to buy in additional product to meet contract demands; to ensure the crop meets the customer specifications ie is free from pests and diseases, is the correct and marketable size and is the specified colour and shape for the market niche.

Figure 7: Showing main goals, sub-goals and information requirements for Brassica production.

Sub-goals
As figure 7 above illustrates the grower attempts to satisfy a number of sub-goals to ensure a maximum yield, high quality marketable product. The completion of each of these may affect more than one higher goal, for example the selection of the right variety is vital because it impacts on the size, shape and colour of the product as well as its harvest date and potential yield. The right field has to be selected for the crop (or the crop for the field) and the impact of its particular characteristics on scheduling taken into account. Some fields for example may be exposed or closer to the sea and therefore add several weeks to the average harvest times; soil type and drainage may also impact on crop timing and yield.
Scheduling has to take existing sales figures into account and leave room for potential changes in demand e.g. a rush on Brussels sprouts at Christmas. The effect of day length and temperature on the speed at which different varieties of crop become ready for harvest has also to be considered. Unlike most manufacturing situations advance product scheduling can only be a rough guide to delivery because the environment into which the crop will be placed is extremely changeable; additional effort is required to predict the exact harvesting date closer to the event e.g. a head of broccoli can grow from small to sale size overnight at certain temperatures and humidity levels. Advanced knowledge of harvest dates is of key concern to those responsible for marketing.

Planting distances vary according to the crop being planted and also according to the requirements placed upon it. Planting distance directly effects the yield and size of the product, and sometimes its shape/colour as well, therefore the distance chosen is based on the particular strategy being adopted by the grower at the time.

Success in avoiding or detecting and destroying pests and diseases and the maintenance of good nutrition has a major impact on the marketable quality of the product as well as the yield. All markets demand high quality and the supermarkets in particular expect zero damage/pest levels in their produce.

These goals are heavily interrelated, and, in trying to meet one the grower may have to take into account aspects of the others, for example reducing planting distance to increase the yield will reduce the size of the final product and conversely increasing distance to produce larger individual items will reduce the potential yield.

Information
The grower has to make decisions about the best way to achieve each goal, and each decision is based on a variety of available information. The quality of this information will therefore impact directly on the growers ability to achieve the key aim of selling all the product at the best market price. The type of information currently employed by the grower (and/or advisor providing the agronomy service) is detailed on the far right of figure 7 above. As illustrated, much of the information is based on past experience and isn't currently stored, although it could be gleaned from careful inspection of the paper based historical records kept by most growers. A few of the larger companies are now transferring this information to computer databases.

Information on varieties is usually obtained from external experts e.g. seed companies, NIAB and advisors/consultants although most growers also run their own field trials each year. Information can be obtained externally from existing sources ie on pest and disease control chemicals, nutritional requirements and meteorological data. The type of information which is more difficult to access is the dynamic variety ie the level of pests/diseases currently in the crop, the level of nutrients in the soil, the size of the crop, the weather tomorrow; all of which have to be gleaned from human observation in the form of field walking and extrapolation from known facts and past experience. While all growers do some field walking many of the medium sized and larger ones employ advisors or other external bodies to do it for them as increasingly their time is taken up with other things.
4.4 INTERFACE ISSUES

The following section is composed of items of relevance to the design of the user interface.

1) Advisors and growers have different interface needs, however both would like an integrated method of storing information, the ability to make changes rapidly, to do 'what if' scenarios and to adjust the system to suit their own particular needs.

2) Advisors works in hectares & acres, growers work in fields and plots, beds and rows (see fig 8). It is vital for any system which stores information to be able to work in at least the plot unit and preferably the bed unit as well. Most growers practice field splitting, having more than one variety or harvest date in the same field. This is particularly true of on-line spray records as only one plot in a field may be sprayed and this must be made clear to any visiting representatives from supermarkets etc. If any doubt about the residue levels exists the business could be lost.

3) Some form of visual representation of fields, often rough, is used by almost every grower with the possible exception of the very largest. However those who hire land do not know what the shape of next years field will be so any interface which uses a visual representation would have to facilitate rapid creation of new field maps. People responsible for scheduling spraying and harvesting often use OS maps to plot routes and reduce the amount of travel required by the often large and cumbersome machinery. Advisors do not do this type of work. The larger grower is similar to the advisor in that they have a great many fields and often rent others so the fields and the distances between them change each year. Maps are also used to identify areas to be sprayed and are kept as part of spray records.

4) Advisors, marketing people and people who do the scheduling work from tons of product per week required (or no. of product) which they convert into the
number of hectares required. The grower translates this into which field or which plot.

5) Advisors focus on the characteristics of the variety not of the field, the grower is also interested in the field.

6) Both advisors and growers use a term like 'period' to define a lump of time during which x amount of crop will be planted/harvested ie Period 1 may be March 11-21st, Period 2 March 22nd - April 3rd etc. The growing year is divided into these 'periods' and all scheduling documents refer to them.

7) Whilst advisors may be familiar with and understand scientific terminology such as 'dry weight' the grower will not and will expect to be able to use wet weight, yield etc.

8) It may be necessary for some information to be encrypted or 'hidden' from the casual observer as the market is very competitive and paranoid.

9) All users would like to be able to add their own comments to files.

10) Marketing usually work on a 3 week time period around harvesting; the farm provides them with the planned harvest figures for the following week and predicted figures for the next two weeks.
4.5 SYSTEM DESIGN ISSUES

The following section contains items of relevance to the production of modelling or other decision support systems.

1) Varieties change every 2/3 years. A modelling system which contains variety information will have to be easy to update from readily available information.

2) Anything which allows the grower to cut down on the number of sprays used would be seen as useful by many as the cost is high, eg for the smaller grower a saving of 3K per annum is possible. For the larger grower however, driven by the requirement for zero pest/disease, the aim is probably more for better timing than reduction; as far as the supermarkets is concerned even a dead aphid on a vegetable is unwelcome. The larger grower may even spray when a forecast suggests it not needed.

3) Any system which could incorporate local historical data to 'fine tune' it would be better received by a sceptical user population. However some growers stated that any information would useful as long as they knew its potential accuracy in advance.

4) Any system which could support the grower in scheduling ie putting the right crop in the right field at the right time, would be considered useful.

5) Maturity forecasting systems are more likely to be of use to the marketing department than to the farm manager unless they can be more accurate than the person in the field. They have to be specific to the week or the farm manager will not find them useful for planning harvest, a rough idea of availability is however of major import to the person selling the produce. This is not true of co-ops who may have 40 or 50 fields to cut at one time and indeed the calabrese predictor was popular with both the co-ops interviewed.

6) Models using met data should state at what distance from the met station the model becomes unreliable.

7) Any decision support tool should, where possible, enable the user to choose between market strategies e.g. yield vs. size.

8) The ability to predict the residual levels of nitrogen left from the previous crop would be considered useful as would knowledge about trace elements.

9) Advisors would like access to up to date fertiliser prices and chemical information, growers would like access to up to date market information.

10) The size of the crop is important and should be taken into account in harvest forecasting models e.g. optimum size for carrots is 24-32mm diameter, turnips 40-80mm diameter, Brussels sprouts 37-41mm.
11) The possibility of vandalism may prove a barrier to investment in weather stations by growers close to urban areas.

12) A curious difference in attitude to spraying exists between growers in co-ops and the independent grower, the first will spray more than necessary to avoid any possibility of pests/diseases, the co-op grower may resist the co-ops desire to spray because of the cost.

13) A wide range of types of record are kept by both advisors and growers. Most small and medium sized growers seem to keep scheduling, planting and harvest records, orders and sales and spray records in paper format, often in books. Advisors may keep daily planting records and certainly keep all previous client records. Spray operators are required to keep spray records by law and a separate copy is also kept by the farm manager for inspection by customers (supermarkets). Historical data is used by both growers and advisors to help plan next years cropping schedule. It was often stated that the ability to keep all the information together would be invaluable.

14) Sampling for input to models is unlikely to be done 'scientifically' by growers, they simply do not have the time. Models will either have to be tolerant of this or carry disclaimers. Advisors feel that models sold directly to growers will not be given time to be adequately field tested and improved and will therefore lose grower support very quickly.

15) Both growers and advisors make use of 'critical fields' to identify the presence of pests/diseases ie they use past experience to judge where a pest or disease will first appear.
4.6 FUTURE TRENDS
There is an increase in the amount of paperwork associated with a crop, particularly for the larger growers who for example have to produce 'plant passports' to say where a plant was grown. The supermarkets in particular are keen to be able to track any given produce back to the field in which it was grown as part of the drive towards reducing the use of pesticides by Uk and European legislatures and by the buying public.

ICMS or Integrated Crop Management System (or IPMS - Pest management) is being pushed by all the supermarkets - particularly Tescos and Sainsburys. Goods sold under Tescos 'Natures Choice' label must conform to Tescos specifications for 'reduced pesticide levels' ie growers may use only chemicals from a reduced list and have also to justify chemical use by keeping field walking records, trap contents etc. The ability to keep good records is therefore increasing in importance.

This is part of the supermarkets involvement in Total Quality Management schemes. Supermarkets are keen on the idea of developing lean and efficient supply chains after the Japanese style, suppliers become 'sub-contractors' involved in 'partnership sourcing' and all work together towards the same goals based on a philosophy of continuous improvement. This idea is being pushed quite strongly by the DTI in many sectors. The implementation of this plan may mean a reduction in the number of suppliers supermarkets will buy from and will certainly mean the growers (and anyone who supplies them) having to comply with the supermarkets IT requirements.

The supermarkets requirement for zero pest/disease damage is likely to ensure that protective spraying continues, as no grower will be prepared to risk pests or diseases taking hold of the crop.

The move towards computers is gathering pace, most smaller growers are buying them because their accountants suggest it or their children think it would be a good idea, most larger ones are looking to match their systems to the supermarkets. The computer literate generation is growing up and in many cases reorganising the business.
5.0 CONCLUSIONS

The need for prediction/forecasting models
Based on the results of the studies carried out in this report it would seem that there is a need for prediction/forecasting models in the grower and advisor populations. There would also seem to be a need for other decision support tools and for a cohesive system for storing and retrieving farm records.

Prediction and forecasting systems would appear to be of most use to advisors and consultant groups and to Co-operative groups. Anyone involved in marketing in the larger companies would be interested in any system for predict the quantity of product they have to sell at a given time.

Technological and informational infrastructure
Although there is not currently a 100% take up of computer technology in the grower and advisor groups there are a considerable number in use and the trend is growing. The vast majority of machines are DOS based IBM compatible and many are also capable of running Windows. It would seem therefore that the circumstances exist in which some forms of modelling information could be made available to growers and advisors as DOS/Windows based prediction/forecasting programs.

The form of the modelling program is important because the type of meteorological data to which the growers in particular have access is rather limited and rarely specific to the fields in question. Models which rely on rainfall, min/max temperature and windspeed and are not too particular about the distance from the source of the data will be most successful.

Which prediction/forecasting models?
Pests, diseases and nutrition were all seen as important. Key pests are cabbage root fly, Brassica aphids and caterpillars and carrot root fly. Key diseases are any which produce spots particularly Alternaria, Ring spot and white blister, Mildew and Botrytis. Key Nutrients are Nitrogen, Phosphate and Potassium, Magnesium and Manganese.

Constraints
Growers operate in an increasingly cut-throat world in a market which routinely overproduces by 40%. Twenty people run most of the vegetable producing businesses in the UK all looking for contracts from around 5 main supermarket buyers. Supermarkets are the main driving force behind changes in the industry, they are seen as extremely valuable customers but very unfair and immovable in their demands for quality and lower prices. As one grower put it "the only difference between a supermarket buyer and a terrorist is that you can negotiate with a terrorist". Any development should look carefully at the type of programs being set in place by the supermarkets under TQM as the larger growers will only be interested in compatible systems.

Knowledge is money. Since the separation of near market and basic research and the drive to obtain direct funding from the growers for the advice they receive an
atmosphere of secrecy and mistrust has developed. Anyone who has knowledge
which might be marketable will be very reluctant to disseminate it or to contribute
another organisations research program. This might limit the types of model to
which the project has access but more importantly may make it harder for systems
to be adequately tested in the field prior to any eventual future commercial
development.

One of the key problem is marketing, one advisor suggested that growing the crop
wasn't a problem, selling it was. Any systems which help to guarantee the delivery
of marketable crops may also help to reduce the level of overproduction.

For modelling systems to be useful the difficulty in acquiring current dynamic data
will have to be taken into account, either by focusing on those models which make
use of easily obtained information or by the development of simple to use, easy to
maintain collection systems. There is a wealth of information hidden in growers
yearbooks. This could usefully be incorporated into models to tune them to local
circumstances or could be gathered as case studies for the development of future
modelling systems. A useful activity might be to develop a system which could
support the grower in maintaining records on computer and in extrapolating useful
information from them. As well as being useful for the grower some formulation of
the rules the grower uses when making decisions would be a useful way of ensuring
that the valuable information about the land and local conditions contained within
the growers head is not lost to the next generation.

Time is an increasingly precious commodity for all growers. The larger ones are
contracting out more and more of their time consuming field walking tasks to
consultant agronomists. No grower will willingly take on a system which requires
the investment of more time unless it offers substantial benefits.

Role task requirements
It would seem that the first target for the prediction/forecasting models would be
the advisor and the co-operative groups. The systems should be designed to be
usable by the farm and harvest managers in the co-operative groups and by any
advisor/consultant. As each of these groups has their own systems in place a good
deal of flexibility in tailoring input and output fields may be required. Key areas for
decision support systems are scheduling, harvest prediction, pest/disease
forecasting, nutrition and planting distances. Any models in this area which do not
require unusual meteorological data as input would be a good starting point.

Another as yet unexplored area where prediction/forecasting systems may be of
even greater importance is in organic production. The timing of planting and
harvest to avoid certain pests and diseases will be of even greater importance to a
group of users who cannot resort to chemicals if things go wrong.
APPENDIX B:
GRIME Interface Requirements Report


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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User interface features for modelling output
Feedback from the industry

May 1996

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APPENDIX A: Demonstration of interface design.
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1.0 INTRODUCTION

This document describes the initial design and testing of a user interface design. The interface in question has to facilitate the interaction of growers and consultants with a range of HRI simulation models. The interface design could eventually be used to present the output of all models developed for HRI within the GRIME HIPPO environment. As more than one model is likely to be used by the same enterprise the design has to be as generic as possible and cover all the main task features required by the target audience.

Interface design
The results of previous interviews with users (GRIME 1.0) suggested that the user interface needed to provide several things in order to be successful:
- present the user with the information they needed immediately, growers spoke of having 10 minutes in the office between jobs and of needing to check disease/pest status within that time.
- present the user with all the main features of the information they need and with simple methods of changing parameters. Those interviewed were very impatient with systems that insisted they go through layers of menus to change key parameters. Direct manipulation of information seemed to be essential. Time is always of the essence.
- present them with the output of several models at the same time. Being able to see the status of several pests and diseases or of other areas of interest is important to the user when making decisions and prioritising information.
- allowing users to see the results of changing variables and comparing the results of several changes on the same screen. In order to make a decision between two or more possible solutions or potential outcomes the user needs to be able to see the results of their manipulations on the screen at the same time.

There were two stages to the design of the interface. The first interface design focused on the means of getting information into the system and on changing the parameters behind graphical and tabular output. This design was developed in Visual Basic™ and used to test the flow through of code from HIPPO to the user interface module. This method was useful in identifying many of the things that the user interface integrating module i.e. RHINO would have to know about the model in order to be able to display the appropriate information to different levels of user.

The second stage of interface design and the one which is described below was conducted using an animation and presentation package called Macromind Director™. This software was used to rapidly design and animate a sequence of potential actions for demonstration to users. Unlike the Visual Basic approach there is no real 'code' or functionality associated with the design, it therefore takes a small fraction of the time to produce and is very easy to adapt to user comments.

The essential components of the user interface design are described below. The design was based on all the points raised above and also on the principle that it had to be generic. This design or one based on it could be used as the basis for interacting with a wide variety of simulation models. Non-time based models would require a slightly different approach.
Figure 1 shows the screen as it might appear as soon as the user opens up the application. The models of interest have been pre-selected and automatically run on start-up to present the user with the current status of the pest/disease immediately. The screen design is loosely based on Windows™ but there was not sufficient time to standardise it to the Windows and Windows '95 guidelines or to pay much attention to the more common human factors interface guidelines (e.g. use of pattern as well as colour in graphical displays).

The main display area shows recorded, or past, information to the left of the vertical bar and forecast or predicted data to the right. The line itself represents the current date. The display shows meteorological data which the user has chosen by selecting the appropriate checkbox on the met data panel (see figure 2).

The items the user is most likely to want to change have been left on the screen e.g. field name, crop, variety and source of meteorological information were considered to be the most important and most frequently changed items. These are changed by simply pulling down and highlighting a new selection (see Fig 3). The scroll bar on the side of the area indicates that there may be more, possibly less important items that can also be changed in this way.

The ability to select and pre-select models to run is provided by the box in figure 4. As models are installed in the users system they become available by pulling down the arrow menus and highlighting the associated checkbox.
There are two types of simulation model which the interface will have to be able to handle, models of biological process e.g. development of aphid population and models of the interaction between a chemical and the biological process e.g. the effect of spraying on the aphid population. The second type of model is particularly important to the grower/consultant, although few currently exist. The interface needs to be able to allow the user to select a chemical or product, make that choice visible on the screen and to indicate where a model of chemical action is available for use. Figure 5 illustrates one method of presenting this information.

As there are two types of model, spray and development, the interface has been provided with two buttons for running them independently as shown in figure 6.

The display features area (figure 7) allows the user to determine the type of display they see and the mode in which the models are run. The view can be altered to a weekly, monthly, or yearly based timeline and the graphical display can be viewed.
as a single window, as in figure 1, or split into 2 or 4 screens. This latter facility allows the user to view the results of several model runs at the same time.

Although not shown on this display or in the demonstration, users were presented with the suggestion that they might also like to see a 'trace' of a previous run instead of a split screen i.e. a faint dotted line to represent the previous position of variables.

The user is also given the choice to automatically or manually run the models. This is to ensure that users do not have to wait for the model to run each time they make a change but can make several changes at once and then elect to run the model.

Figure 8: Changing values on the graphical display

In common with many new object oriented pieces of software this interface assumes that users will find it easier in some circumstances to directly manipulate the data on the screen. Figure 8 shows the user changing the amount of precipitation forecast for a given day by dragging the data point to the preferred position. The new figure is given in a data box in the top right hand corner of the screen, in which the value can be directly entered if preferred. Large data changes should be made using a tabular, spreadsheet type format which can be accessed from one of the menubar options.
2.0 TESTING WITH USERS

Method
Six farmers and one adviser were introduced to the interface design as shown above and to the earlier version containing file manipulation and data manipulation facilities. The concepts behind the design were explained in the context of semi-structured interviews lasting between one and one and a half hours. Each user was informed that the system was a demonstration tool and in a fairly early stage of development. Users were asked to point out interface features, wording and dialogue structure which caused them problems e.g. didn’t make sense or irritated them.

The interviews took the form of a ‘walkthrough’ with the majority of button presses being carried out by the interviewer. At each stage in the dialogue users were asked standard questions about particular features of interest. They were also asked what they thought they were supposed to do at each stage and whether they understood the purpose of the window and the method of interacting with it. All interviews were tape recorded with the permission of the interviewee.

Interviewees were told that certain types of question they may want to ask can be answered by model based simulation software. Examples of the questions were given, e.g. questions about:

- choosing the most cost effective options:
  - when to spray - fertilisers, insecticides, fungicides
  - how much of x to use to get maximum benefits, minimum cost;

- targeting a particular market:
  - when is harvest likely
  - when should I plant
  - how can I get the crop to look like this

- managing the crop
  - when will seeds emerge
  - when should I irrigate
  - what will the crop look like if I do this

Interviewees were told that ‘models to answer some of these questions are being, or have been, developed by research institutes. While the models for each question and for different crops/pests/diseases might be very different they have some similarities:

Input - they require data to be put into them (weather, crop, field data)
  - the weather data may be entered by hand or by a logging device
  - the user will want to be able to edit the data

Output - they have to display the results of calculations in a meaningful way
  - the user will want to compare a number of alternative calculations

There are many ways of doing all the above, some better than others. We have attempted to identify some common interface features, which could be used by all models because the use of a common interface style will mean that you will not have to learn new ways of doing things with each new model you buy.
To try to ensure that these interface features do what they are intended to do, i.e. support you in making decisions, we would like you to give us your opinion of the screens that you see.

Interviewees were told that the software was not complete and in fact in some cases was little more than a picture on the screen.

After this introduction the users were asked what type of question they would like better answers to or more support with. They were then taken through the screen design and at each stage asked:
- what they thought the screen was for
- was it what they expected
- did they understand what to do next
- did they understand all the terms being used.

The interviews were recorded and the comments collated.

3.0 RESULTS

Aphids and caterpillars were the models that most brassica growers wanted access to. To be of most use however they have to be linked to information about control because the questions that users want to answer are: "which spray should I use?" "when should I use it?", "Can I get away with waiting until next week?", and "what effect will the weather have on the spray application?". Models of Alternaria were also mentioned as were models which help them predict the number of heads (or tons) of broccoli/calabrese ready for harvest on a given date. One of the sample felt that pest models should take into account predator numbers which have quite an impact on the need to spray.

The general approach of the screen layout shown in figure 1 was appreciated by all the interviewees, the speed of access was especially appreciated as 'scientists have 8 hours a day to play with it and farmers only have 5 minutes'. They also liked the idea of keeping all the HRI models in a single area accessible by a single package.

The graphical display was seen as easy to use and useful by all of the interviewees, as one of them stated 'it would help me see that I need to spray on such a date and I could then plan rest of activities around that spray' and another said he liked its resemblance to his data management package 'Its very Optimixy - its the way they do it'.

The graphical display of met data was also appreciated, 'its easy to move and to see' seemed to be the general response, and they all liked being able to pick up and change the data levels dynamically. On the negative side several users said that they would like to be able to change all of the met values by one or two points at once i.e. reduce the general level of rainfall by a few centimetres. The tabular display for entering met data (not shown in this document), was also criticised because users weren't able to enter data directly into the cells.

The ability to 'tweak' the met data and the spray dates was seen as very valuable. This type of 'what if' manipulation being particularly important for making decisions about risk assessment, workload and tank mixes. There were mixed
opinions on whether the interface should offer a dotted line trace of previous position or a split screen view.

The consultant in our sample pointed out that the use of a single field view was not useful to the adviser or the larger grower, who will wish to work on the basis of enterprises or blocks instead. The same person was also keen that any such system be capable of running automatically in the background and producing print-out warnings whenever there was a danger of infection or other similar event.

Other points about the display included the need to make the thresholds for pests and diseases obvious on the screen and to show the information as a percentage risk. There was also a suggestion that all names be in English and not Latin.

One of the sample felt that the system should be more proscriptive and provide verbal guidance on tasks.

4.0 CONCLUSIONS

The 'one stop' interface as illustrated by the design in figure 1 appears to be an acceptable way to present model based information to both growers and consultants, provided some of the problems are overcome, in particular the need to be able to view enterprises and groups of field and not just single fields.

The majority of simulation models could be represented within this type of layout and could be understood and interacted with by those normally responsible for making spray and harvest decisions. Users are particularly happy with the method of direct manipulation and of being able to see the results of 'tweaking' inputs.

The interface design is by no means complete however and much more work is needed to develop the ideas into something which would be both practical and commercially attractive. The key changes suggested by this sample are the introduction of direct data entry into cells, use of more common terms, clearer indication of thresholds and risk levels, the choice of trace or split screen, and the ability to change all met values by a few points.
APPENDIX C:
DESSAC First Phase User Requirements Survey
(and appendices)


By
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Initial user requirements survey

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Decision processes for winter wheat.
User requirements for future decision support systems.

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EXECUTIVE SUMMARY

During 1993 and early 1994 discussions between MAFF, HGCA, crop agronomists and researchers, as well as representatives from the agrochemical industry, developed a series of ideas on arable crop decision support systems (DSS). These culminated in a project proposal, supported by MAFF and the HGCA Research and Development committee, which would be part of the MAFF Link programme on technologies for sustainable agriculture.

In view of the ambitious nature of this project and the need to establish clear user requirement baselines, MAFF has provided funds to allow some preliminary work to take place during the current financial year ending in April 1995. This support has enabled the first phase of the determination of the user requirements to be undertaken.

A preliminary investigation was undertaken into the needs of future decision support tool users in the cereal industry. In particular it aimed to determine the potential range of users, the different requirements they may have, the information sources they currently employ in decision making, the value of these sources and their understanding of what would help them to become more efficient.

Section 2.0 of this report describes the methods used to gather this information and Section 3.0 summarises the results obtained. A discussion of the results is provided in Section 4.0.

The conclusion of the survey was that, in view of the consistency of findings reported, the group shift focus away from high level requirements analysis to more detailed developments. It was also recommended that initial development of system modules should focus on the 'decision support areas 'choice of varieties' and 'choice of chemicals'.

Finally the view of the future decision support system which emerged from this survey is one of a portable, user friendly device which links into the communications network and other recording devices and supports the user by providing access to information (databases), confirmation of decisions, advice and 'what if..' scenarios.
1.0 INTRODUCTION

During 1993 and early 1994 discussions between MAFF, HGCA, crop agronomists and researchers, as well as representatives from the agrochemical industry, developed a series of ideas on arable crop decision support systems (DSS). These culminated in the establishment of a steering group early in 1994 which has now formulated a project proposal, supported by MAFF and the HGCA Research and Development committee, which would be part of the MAFF Link programme on technologies for sustainable agriculture.

In view of the ambitious nature of this project and the need to establish clear user requirement baselines, MAFF has provided funds to allow some preliminary work to take place during the current financial year ending in April 1995. This support has enabled the first phase of the determination of the user requirements to be undertaken.

This report presents the results of the initial interviews with two discrete groups of potential users. These interviews were designed to identify the information needs of users, the sources of that information, and the interactions between the individual decisions that make up the range of actions in arable crop production on the individual farms.
2.0 METHOD

2.1 Design
As previously stated, the purpose of this survey was to examine the decision processes relating to arable crops and to determine in which areas decision support systems might be of particular relevance to users.

2.2 Users
It was agreed that anyone who currently makes use of complex information to aid in the production of arable crops is likely to be a potential user of the projected decision support systems. For the purposes of this study therefore three main classes of users were identified, farmers, chemical representatives and independent advisors. Chemical representatives and independent advisors were considered to be different user groups as they were seen to have different objectives and thus potentially different requirements.

2.3 Sample size and selection
Names and addresses of farmers and advisors were produced by ADAS Ergonomics Unit and Morley respectively. The farmers were randomly selected from an existing ADAS list; it was hoped that by this means a representative range of farm sizes and interests would be included. An additional form of selection occurred prior to interview as many of those contacted were unable to make themselves available, time constraints being the most frequently cited cause.

To make best use of the geographic location of the investigating partners HUSAT concentrated its efforts on the North and Midlands counties i.e. Lincolnshire, Cambridgeshire and East Anglia, whilst ADAS Ergonomics focused on the South e.g. Kent and Sussex. A total of 11 farmers, 4 advisors and 2 chemical representatives were interviewed over a period of three weeks during September 1994. The 4 independent advisors included 2 from ADAS.

2.4 Materials
The interviews were structured and standardised by means of a questionnaire, a copy of which can be found in Appendix A. All interviews were recorded with the permission of the interviewee.
2.5 Procedure

A letter of introduction (See Appendix B) was circulated by Morley, to those farmers and advisors previously identified, setting out the nature of the project and requesting their co-operation. These individuals were then contacted by telephone by either HUSAT or ADAS Ergonomics and interview dates organised.

At the start of the interview the respondent was given background information on the project work being undertaken. They were then asked to state the area of arable crops they grew or provided advice on and to list any other crops they were involved with. The bulk of the interview took place in two parts. In the first part the respondent was asked to imagine they had already identified a market for a crop of winter wheat. (A decision had previously been taken by the Link group to focus the research on a single major crop; winter wheat was chosen).

The respondents were asked to talk the interviewer through the growing year outlining the decisions that had to be made in relation to the winter wheat crop. During this process, which took up more than half of the 1-1.5 hour interview slot, the interviewer asked questions as to the nature, source and importance of information used to make decisions. A list of standard 'prompts' were used (see Appendix A).

In the second half of the interview the respondent was asked to provide answers to a number of short 'checklist' type questions (see Appendix A for more detail). These were designed to elicit further information about the nature of a number of previously identified decision points, namely; What crop to plant; Planting time; Crop variety; Harvesting time; Scheduling work; Choosing chemicals; When to spray; Safety Issues; Financial matters. The topics covered were:

- The complexity of the decision
- The source of information (paper, person or computer)
- The desire for easier access to information sources
- The location of the decision process (field, farm office or house)
- Time taken to make the decision (immediately, minutes, hours or days)
- Confidence in the accuracy of the decision when made

Additional questions were asked about use of computers for word processing, accounting, farm management, information storage and retrieval and communication purposes and the users willingness to employ them in the future if
they did not already do so. The respondents' previous experience with decision support systems was also noted.

The final part of the questionnaire asked the respondent to use their imagination to describe to the interviewer a system which would answer all of their farming information needs. They were told not to limit themselves to today's technology but to describe the features they would like in an ideal world and the uses they would make of it.
3.0 RESULTS

3.1 Sample profile

Table 1: Showing cereal acreage of farmers and advisors participating in the study

<table>
<thead>
<tr>
<th>Farmers</th>
<th>Advisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 acres</td>
<td>14,000 acres</td>
</tr>
<tr>
<td>150 acres</td>
<td>8,000 acres</td>
</tr>
<tr>
<td>150 acres</td>
<td>7,000 acres</td>
</tr>
<tr>
<td>200 acres</td>
<td>2,500 acres</td>
</tr>
<tr>
<td>244 acres</td>
<td>-</td>
</tr>
<tr>
<td>280 acres</td>
<td>-</td>
</tr>
<tr>
<td>425 acres</td>
<td></td>
</tr>
<tr>
<td>450 acres</td>
<td></td>
</tr>
<tr>
<td>500 acres</td>
<td></td>
</tr>
<tr>
<td>600 acres</td>
<td></td>
</tr>
<tr>
<td>800 acres</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Showing range of crops covered by farmers and advisors interviewed.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Farmers 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar beet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil Seed Rape</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linseed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed Farms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As tables 1 and 2 above illustrate, a wide variety of farmers and advisors were interviewed during this survey. The acreage of cereals grown ranged from 14 to 800 acres, almost the full crop range was covered by both farmers and advisors and the views of both arable and mixed farmers were included.

3.2 Main findings.

The main findings of the survey are reported below, full details can be found in Appendix C.

Independent and chemical representative advisors

This survey indicated that the roles of these advisors are almost indistinguishable for our purposes. While the aims of the individuals may vary to the extent that
company policy dictates the chemicals/services etc. they recommend to the client, the aim of all advisors is to provide the client with cost effective advice. The clients continued use of the individuals company will depend on its success in the previous year. The common view expressed by farmers is that chemical representatives and independent advisors cost them roughly the same amount of money, they just extract it in different ways. As the information sources and tools used by both chemical and independent advisors to formulate the advice they provide seem to be essentially the same they are therefore considered to belong to the same user group throughout the remainder of this report.

Whose decision is it?
The following table indicates the roles played by the farmer and advisor in the decision making process. The title 'advisor' should be taken to include both independent and chemical representative advisors (see previous paragraph).

<table>
<thead>
<tr>
<th>Decision area</th>
<th>Farmer</th>
<th>Advisor (independent &amp; chem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choice of crop</td>
<td>Main role</td>
<td>Confirmation role</td>
</tr>
<tr>
<td>Choice of variety</td>
<td>Main role</td>
<td>Confirmation role</td>
</tr>
<tr>
<td>Cultivation</td>
<td>Main role</td>
<td>Confirmation role</td>
</tr>
<tr>
<td>When to plant</td>
<td>Main role</td>
<td>Only for new varieties</td>
</tr>
<tr>
<td>Field walking</td>
<td>Role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Need for Pest control</td>
<td>Role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Need for Disease control</td>
<td>Role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Need for Weed control</td>
<td>Role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Need for Fertilisers</td>
<td>Strong role</td>
<td>Fertiliser rep has strong role</td>
</tr>
<tr>
<td>Which chemicals</td>
<td>Not strong but role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Spray rate?</td>
<td>Not strong but role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>When to spray?</td>
<td>Main role based on recoms</td>
<td>Role is to state key date</td>
</tr>
<tr>
<td>Safety</td>
<td>Main role</td>
<td>Weak but role varies</td>
</tr>
<tr>
<td>When to harvest</td>
<td>Main role</td>
<td>No role</td>
</tr>
<tr>
<td>Financial decisions</td>
<td>Main role</td>
<td>Role to provide most cost effective solutions</td>
</tr>
</tbody>
</table>

The table above is based on the roles of the average farmer and advisor and should not be taken to cover all cases. The true state of affairs is closer to a continuum model where there is a large overlap in the centre ground of decision making between farmers and advisors (see figure 1). For example some farmers are very scientifically aware and have the time to make their own spray and chemical decisions, others are extremely short of time and find it more effective to leave the bulk of the non-scheduling decisions in the hands of an agronomist.
This division into scheduling and scientific/information based decisions was seen very clearly in the results of the survey. The farmer has the stronger role in any activity which involves the scheduling of time or resources ie planting, harvesting, when to spray, whilst the advisor plays the strongest role in those activities relating to the application of information based and scientific knowledge ie the need for insecticides, fungicides and herbicides and the best rates of application. The reason for this is that gathering and collating data is a very time consuming and specialised activity and many farmers do not have the time or the expertise to do it effectively.

Decisions to be taken between March and November are particularly susceptible to time pressures; those taken between December and February e.g. variety and market choice are less prone to time pressure and therefore more likely to be carried out mainly by the arable farmer. Mixed farms are of course busy throughout the year and are thus more likely to leave all scientific and information based decisions on their wheat crops to an advisor.

The survey would seem to indicate that the more valuable the crop the more advice the farmer will seek. Where the potential for loss is great, the stress on the farmer is enormous and in many cases it would seem that the advisor also has a 'reassurance' role ie assuring the farmer that the decisions they have taken were the best ones. Trust in the value of the advice is critical, many farmers have known their advisors for years and believe that, on the whole, they are being provided with the best advice possible for their circumstances. It in fact may be necessary for the farmer to
have this level of faith in the advisor, to reduce the burden of stress incurred by high credit levels and high value crops.

In general it would seem that farmers depend heavily on their consultants for technical advice, and in some cases this dependence verges on blind faith. Farmers accept that they cannot keep abreast of all the relevant information themselves and must therefore accept the help of a third party. This is particularly true in the area of chemical selection, i.e., one farmer, who appeared to run an efficient business said:

"I find the whole thing increasingly confusing (chemicals) because what they are doing is issuing the same chemicals but under different names...."

The value of the consultant is judged purely on crop performance, however farmers can only base their judgements on things that go wrong, they cannot judge whether an acceptable performance could have been better.

Financial decisions made about the crop are primarily the responsibility of the farmer, however the advisor also has need of support in this area as their task is to provide the most cost effective solutions to problems that arise.

### 3.3 Information sources

The key information sources, i.e., those mentioned by a majority of respondents, are discussed below. Problems relating to these sources and identifiable gaps in provision are also discussed under each of the main decision area headings. A more detailed description of the data can be found in Appendix C.

**What crop?**

The key information input to this decision is the fields position in the rotation cycle. Where new crops are sought farmers will most commonly refer to market information (from any available source) and the farming press. Previous experience and information from advisors and from friends and neighbours is also important.

There were few problems relating to this area, it received a low complexity rating from both farmers and advisors. Most farmers (7/11) said they didn't want additional support to make this decision although some felt that they would like easier access to market information. Four out of the six advisors were interested in more assistance.
Planting time
The farmers own experience is critical to this decision. Advisors do not play a large role. The use of key dates by farmers is common ie plant between September 20th and October 17th and is moderated by knowledge of the variety; field characteristics; soil conditions; the trade off between yield and the probability of disease; machine and personnel availability and seed availability. Knowledge about the weather is also critical.

Once again there were few problems in this area, farmers felt that their own knowledge was generally sufficient. The complexity rating was low for both farmers and advisors. Most farmers (8/11) said they didn't want additional support to make this decision, 4 out of the 6 advisors were interested in more assistance. Timely information on the availability of seed varieties was highlighted as one area that could be improved.

Variety Choice
Paper based items were most frequently cited as the source of information about crop varieties. The most commonly reported were NIAB and other trial reports, their own field trials, seed company literature and the farming press. The farmer or advisors own experience of the fields characteristics and market requirements are also important. Farmers may also use information on varieties from friends and neighbours.

The complexity rating given by farmers for this decision was higher than for crop choice or planting time and a majority of them (9/11) requested additional support in this area. Five out of six advisors also requested additional support. Timeliness and quantity of information were cited as the main problems. While trial reports were seen as vital, many complained that they didn't receive them until after the decision making period had passed. The difficulty of processing a mass of data from many sources led many to see this an area where computers and databases would be useful.

In addition, the results of crop trials were rarely taken at face value; farmers always looked for confirmation that the results had some relevance to the conditions prevalent on their farm.
Identification and assessment of:

**Weed problems**
The nature and extent of the problem is usually determined by observation in the previous year. Sources of information for where to spray are often hand drawn field maps showing the location and density of each weed population.

Recording the location of weeds accurately year by year was seen as the main problem in this area. The introduction of satellite technology and of CD ROM storage were felt by some to be potential solutions.

**Insect and disease problems**
These two areas have very similar sources of information. They both rely on observation for initial identification and assessment of the level of risk. Identification relies primarily on the experience of the observer. Assessment of risk requires knowledge of the value of the crop (gross margins), the usual impact of the pest or disease (pest life cycle) and knowledge of the effect of environmental variables such as time of year and current weather patterns on the progress of the pest. Knowledge about the weather is particularly important to the assessment of disease risk.

Field walking is carried out regularly, its frequency ranging from three days to three weeks. The frequency changes based on the time of year and knowledge of potential risk gained from: advisors; farming press; newsletters; forecasts and local information.

The information sources called upon to supply data about pest effects and lifecycles are: past experience; trials data from any source; scientific papers and reports from research establishments and the farming press.

Insect control is generally only used when the pest is seen to be a problem whilst a certain level of fungicide is often applied as a matter of course with additional doses as perceived necessary. The planning of fungicide applications then can to some extent take place prior to the establishment of the crop.

No major problems concerning diagnostic information emerged from this area. While the farmers may not be sure of the nature of a problem they are in general happy to rely on the experience of their advisors. Advisors also have external
sources to call on if their experience fails them and appear to have no need of additional decision support in this area.

Additional forecasting information would however always be welcomed. While existing sources seem to be adequate in transmitting knowledge of pests and diseases when they occur, more detailed information regarding the likelihood of attack would be beneficial. Advisors sometimes find scheduling of field walking in response to a warning problematic. As they are responsible for a large number of fields, they have to determine which are susceptible to the forecast attack and to plan a walking regime which covers the area in the most effective way. As this requires manipulating 'more than a head full' of data, mistakes may occur.

Advisors also have difficulties collating information on new research into pests and diseases from a wide range of sources. Many provide an information service for their clients which involves summarising data of particular interest to them. This is still largely a paper based operation and as such is extremely time consuming.

What to spray
Knowledge about which chemical is appropriate for a given task is obtained from advisors; notes produced by the chemical manufacturers; chemical company data sheets; advertising; and trial data from any available source. The decision about what to spray is based on this knowledge plus information about the price of the appropriate chemicals, the extent of the problem and the value of the affected crop. In the south particularly, farmers are also likely to consider the environment impact of the chemical and where a choice exists, to choose the least damaging type.

This area was given a high complexity rating by both farmers and advisors and both groups indicated a desire for additional assistance (9/11 farmers; 5/6 advisors). Farmers often said they would like to be able to understand the reasoning behind the choice of chemicals made for them by their advisors. As in previous areas, easier and more timely access to trials information would be useful.

When to spray
This decision uses information from people based sources. In general the advisor will suggest the optimum spray time and then the actual timing is left to the farmer to arrange, based on scheduling demands. Where contract sprayers are employed, the need to scheduling a range of clients work is a constraining variable.
Spray timing was seen as a complex decision by many of the farmers and by some of the advisors and there was some support for the provision of additional assistance (6/11 farmers and 4/6 advisors said they would like additional assistance).

**Nutrition**
Field records and soil tests are the most important sources of information about the condition of the field. Soil tests are usually conducted by the fertiliser companies and advisors; these people will recommend a level of nutritional supplement based on the results of the tests. Fertiplan and Optimix (commercial computer programs) are also used to provide decision support. Additional information sources are: the condition of the crop (observations); the value of the crop and the availability of manure (mixed farms). Satellite information on field health is being used by a number of farms for the first time this year.

The need for information specific to areas of the field were seen as important with regard to nutrition and to yield. The driving force behind this appears to be set-aside and the possibility of taking poor land out of production. The ability to change the rate of nutrition as the sprayer passes over various areas of the field was felt to be useful for both ecological and economic reasons.

**When to harvest**
This decision is usually taken by the farmer. Two main factors determine the date, the readiness of the crop (usually indicated by moisture meter or by 'bite') and the weather. While the rule of thumb appears to be 'cut as soon as possible', there is a trade off between the need to be finished before the weather breaks and the desire to cut the costs of drying indoors. Increasing pressure for drier grain from the buyers is making this decision more crucial to the farmers profit margins. Weather forecasts provide an important input to this decision as does knowledge about the availability of people and machinery on the larger farms.

This decision area received a low complexity rating and while advisors requested additional support (4/6), most farmers felt it wasn't necessary (9/11). The main problem reported in this area concerned the local accuracy of weather data: it would appear that any improvements would be welcomed.

**Scheduling work**
Scheduling of work is a task which requires mostly human input. The decisions are often difficult to make in advance because of the vagaries of weather and
pest/disease occurrence. The decision area was given a fairly low complexity rating but there was some desire to have additional support provided, 6 out of 11 farmers and 5 out of 6 advisors said they'd like assistance.

Accurate local weather data and support in targeting activities (i.e., field walking) would be seen as useful.

**Safety issues**
Decisions about safety tended to be seen as fairly low input, low priority, particularly on the smaller farms. The key information sources for safety-related issues are paper-based (i.e., the data sheets supplied with chemicals and the COSHH regulations).

Safety decisions were not generally seen as complex and most farmers said they were not interested in additional assistance (7/11). Four out of the six advisors said they would like assistance and suggested that some method of collating safety data (to enable them to produce reports for their clients) would be welcomed.

**Financial issues**
Information necessary to make financial decisions is obtained from many sources, e.g., commercial data, Nix, accountants. On farms, the source of information is largely people-based; advisors, however, seem to place a greater emphasis on paper-based sources. Many farmers carry out gross margin analysis and they also use information from growers' groups and from the farming press. The advisor is expected to provide the farmer with the most cost-effective solutions.

This area was considered by most respondents to be highly complex but perhaps surprisingly only 6 out of the 11 farmers requested additional support, in contrast to the 5 out of 6 advisors who felt assistance would be useful. The one financial area where a number of farmers expressed concern was in the choice of chemicals. Farmers are not always sure that they are given the most cost-effective advice, particularly where there are vested interests (e.g., advice from chemical company representatives). Both growers and advisors complained that there was a shortage of commercial data available to help them make the best choice for their needs.

The inability to integrate information relating to financial matters (e.g., for gross margins analysis) was seen as a source of frustration by some.
3.4 General Issues

Observational data
Field walking by the advisor is the primary source of observational data, this is supplemented in most cases by walking by the farmer or farm manager. The frequency of walking depends on the time of year and the perceived level of risk. From once every 3 weeks in the slow season to once every 3 days if there are forecasts of disease.

Advisors would like to be able to access information whilst in the field and to make notes for inclusion into reports for the client. Farmer would also appreciate a hand held tool for note taking or for sketching out weed locations etc.

Local information
A general impression gained from the interviews was that users feel there is a lack of local information. Knowledge about the experiences of farms in the same geographical area and of local weather and local trial data was seen by many as essential.

Weather data
The most common sources of weather data are television (Sunday pm particularly), local radio and the met office fax and phone forecasts. A number of farms record their own temperature and rainfall levels.

The lack of accurate and timely local weather data was cited by some as a problem area.

Decision making location

<table>
<thead>
<tr>
<th>Summary</th>
<th>Farmer</th>
<th>Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Office</td>
<td>House</td>
</tr>
<tr>
<td>What to plant</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Planting time</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Crop variety</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Harvesting time</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Scheduling work</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Choosing chemicals</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>When to spray</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Safety Issues</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Financial matters</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 5: Number of responses to choices in 'where do you make decisions' question

October 1994
Planning decisions such as what crop to plant, what variety to use and what chemical vendor and mix to use take place largely in the office or at home, this is also true for financial decisions and for decisions relating to the current weather conditions such as 'can I spray today?'. Field based decisions are generally those which relate to the identification of weeds, pests and diseases and their treatment. The decision to spray is made in the field, as are decisions relating to the type of chemical required and the dosage needed, although preliminary reading will have taken place in the office/home during quieter moments.

The time taken to make decisions

<table>
<thead>
<tr>
<th>Summary</th>
<th>Farmers</th>
<th>Advisors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Imm</td>
<td>Mins</td>
</tr>
<tr>
<td>What to plant</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Planting time</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Crop variety</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Harvesting time</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Scheduling work</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Choosing chemicals</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>When to spray</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Safety Issues</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Financial matters</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

Key: i=immediate, m=minutes, h=hours, d=days

The longest decisions to make concern what to plant, what variety to choose, what chemical vendor and mix to select and decisions relating to finance. These are, with one exception, all the information intensive activities. The one area which isn't mentioned is the choice of chemical, most respondents stated that this took minutes-hours, usually while they were standing in the field. It could be argued that in this case the information has already been processed and is available to the farmer or advisor in memory. Decisions as to the timing of planting, harvest and spraying and decisions about the need to spray were all considered to take very little time ie minutes.

Use of computers

While computers were not used by all farmers or advisors, there were a significant number in use (7/11 farmers, 4/6 advisors). Advisors were likely to use them for all aspects of the business ie word processing, accounting, farm management, information storage and retrieval and communication purposes. Farmers however
appear to be using them most often for farm management tasks and information retrieval and storage.

Of those not currently using computers, only 3 stated that they weren't prepared to, one of these people was approaching retirement, the other two felt that they couldn't justify the cost.

3.5 The ideal system

The respondents produced many interesting ideas about the systems they felt would make their lives easier. The ideas which occurred most regularly can be categorised under 5 main headings; farm data; financial tools, on-line services; databases and advice/utilities. These are summarised below:

Farm data
All farmers who were willing to use computers (see section **) wanted the ability to store farm records. While the method of doing this wasn't specified, the need to be able to keep field maps was stressed. These maps would be linked into other systems such as the satellite system and would enable them to record, display and print out the location and strength of weeds, pests, diseases and nutrition. The crop rotation records would also be kept on disc and may interact with the mapping system.

Finance
One of the most commonly requested functions was the ability to so 'what if...' scenarios relating to finance. These may be concerned with the costs and impact of fertiliser use, or prophylactic spraying, or the choice of a new seed variety, anything which enables the user to play with possibilities and see the likely outcomes of a decision before actually taking it would be seen as useful.

The ideal system would incorporate the cost analysis system they currently use but allow it to 'talk' to and use input from other sources of information. Failing that a simple means of transferring their existing data to a new format would be required.

Several people requested a computer version of the Nix handbook.
On-line services
The term 'on-line' in this context does not refer specifically to a service called up by the user, many users felt the costs of many such services were prohibitive and unnecessary and that they were too time consuming to use. On-line refers to any service which is not located on the users premises ie dial-up services and those which send information to the user on a daily or weekly basis either via the computer or via a fax machine.

Information which the users would like to access by this means are chemical prices, market prices, local weather forecasts, chemical availability, seed availability and disease and pest forecasts.

The need to find out what was going on locally could be fulfilled by use of a 'bulletin board' to which farmers and advisors could contribute.

Databases
These would ideally be disc or CD based and permit easy searching on key-words and facilities to copy information to other files for collating, sorting etc. Users requested databases of trials results, journal abstracts, press reports, other research information, chemical data and prices and safety data.

Advice/utilities
This category brings together all the tools which provide access to scientific knowledge, either in the form of guides e.g. a disease/pest diagnosis programs using photographs on CD ROM, or 'what if...' simulation tools. While this type of system was seen as desirable the point was often made that the reasoning behind advice should be transparent, that no trust would be placed in systems which simply 'gave the answers'.

The scheduling support tool also sits under this heading, if a little uncomfortably. It would be required to support the farmer in scheduling farm jobs to make the best use of people and machines and also to support the advisor in scheduling their farm visits. It would have to be capable of re-evaluating its advice on the basis of other data such as weather or disease forecasts.
System characteristics
The ideal system for both farmer and advisors will be portable and include communication functions. Advisors need something they can work on in the office, in the field and at home without having to constantly transfer material from one machine to another. The ability to 'phone' into the office and pick up new information or query office databases is also required. Farmers too spend almost as much time working on farm business at home as they do in the farm office and will need to be able to keep the same information in both places. A built in fax and printer were suggested by many as desirable. The 'ideal' system would perhaps look something like this:

The main machine would be a powerful portable capable of storing the wide range of information required by advisors and fast enough to cope with the calculations farmers may require it to make when using their simulation tools and gross margin calculations. It would have an in-built modem and fax/printer facility. It would be used as a portable in the car and at home.

For ergonomic reasons it is not advisable to use the portables screen and keyboard for long periods and so for office use a larger screen and full keyboard are required. To avoid problems associated with the transfer of data, these items could be plugged into the portable as external devices, leaving the portable to act as the 'hard disc'.

For field use a pen based notebook would be most useful, allowing rough sketching and form filling activities to take place. These files could then be downloaded into the portable for incorporation into farm records, customer reports etc.
4.0 SUMMARY

The purpose of this survey was to carry out a preliminary investigation into the needs of future decision support tool users in the arable industry. In particular to determine the potential range of users, the different requirements they may have, the information sources they currently employ in decision making, the value of these sources and their understanding of what would help them to become more efficient. It was originally felt that this survey, restricted to a small number of users, would be the first of several, the results from this phase revealing new user groups to be interviewed and specific interests to be clarified.

This view has since changed. The overwhelming impression gained from this series of interviews is one of consistency, the same requirements appearing in almost every case. Instead of a range of disparate groups with differing needs the survey found a continuum, from low tech farmer to high tech advisor, with a large overlap of requirements in the middle ground.

In general the decisions made by the two groups can be categorised as strategic and tactical. Those decisions made mostly by the farmers are strategic i.e. planning decisions such as finance and the scheduling of planting, harvesting and spraying. The advisor tends to focus on tactical decisions e.g. those concerning management of pests and the choice of chemicals.

With regard to the use of computer technology; although computers were by no means used by all the respondents there was little evidence of technophobia. The main reason for non-use was an assumption that the size of the business did not justify the purchase of a computer, for example:

"No computer, never used one. Not really big enough to justify it on this acreage"
"Providing it could justify the price I would have one here, now"

There also seemed to be a feeling that there weren't any programs which suited their particular needs:

"Never used one (Decision support system); I would like to but I have never found one that's any good"
"Although I have not got a computer I have no qualms about using one if it did what I wanted it to do"
The only respondent who was adamant that he would not use a computer was approaching retirement age. However, even he thought that they had their uses and expected his adviser would find them useful.

**SUMMARY OF THE DECISION PROCESS**

The main decision areas identified by the researchers prior to the survey can be amended slightly in the light of the results. The key decision areas can be identified as:

- Choice of crop
- Choice of variety
- Planting time
- Harvesting time
- Scheduling of work
- Which chemical type/what rate
- Which chemical vendor/brand
- When to spray
- Safety Issues
- Financial matters

The area called 'Financial matters' is very broad in its scope, finance is considered in each of the decision areas above as well as on a long term strategic basis.

Decision areas which farmers felt were complex and would particularly benefit from additional support were the choice of varieties and the choice of chemical vendor/brand. There was also some interest in additional support for choice of chemical type, when to spray, scheduling and safety issues.

Advisors, on the whole, would like additional support in any area that will improve the service they can offer to their clients, thereby improving their market position. Areas of particular interest are: choice of crop variety, scheduling of work, choice of chemical vendor/brand and finance.

**SUMMARY OF SYSTEM REQUIREMENTS**

One the basis of the questionnaire and interview analysis it would appear that the system needs to include the following elements:

**Ease of use/ease of learning.**

"I would like to have an easy to understand and operate system for morons like me"
The system must employ interface standards and make use of any available human factors knowledge on the most effective presentation of information.

**Portability**

Farmers and advisors alike have a need to use the system in different locations without the overhead and potential dangers associated with the transfer of information between machines. The system must be capable of running on, and making the best of, a portable format machine.

**Communication links**

The ability to link into the 'network' is important to both sets of users. Farmers will want to be able to 'plug in' so that they can receive information and advisors will also want to search for information.

**Inclusion of local/farm data**

Any design must allow access and input to local information and information "personal" to an individual farm. The ideal system as far as the farmer is concerned would take into account the vagaries of their farm and enable immediate monitoring both in terms of physical and financial performance.

**Types of assistance**

On the basis of the decision areas which users requested additional support in it would seem that four distinctive types of assistance are required:

1) **Information provision** e.g. database of chemicals
   "If you plug into one particular point and get all the information you require, that would be a godsend"

2) **Confirmation of decisions** e.g. checking the suitability of a chosen variety

3) **Advice** e.g. recommending a chemical, recommending a route

4) **Scenario generation or 'what if..'** e.g. examining gross margins of a spray regime.
   "One that worked out 'what if..' scenarios would be great, plus something that could immediately do partial budgets"
5.0 CONCLUSION

It is the recommendation of this report that, in view of the consistency of findings reported here, the group shift focus to the detailed development of the user requirements survey, i.e:-

1) Develop a model of the system based upon our understanding of user needs obtained from the interviews.
2) Test the users reaction to this model on a second sample of potential users and adjust as necessary.
3) Prepare a development strategy for that model from the users viewpoint to present to the steering group.

On the basis of the findings from the survey it is also recommended that initial development of system modules should focus on the decision support areas 'choice of varieties' and 'choice of chemicals'.

The view of the future decision support system which emerged from this survey is one of a portable, user friendly device which links into the communications network and other recording devices and supports the user by providing access to information (databases), confirmation of decisions, advice and 'what if..' scenarios.
APPENDIX A

QUESTIONNAIRE USED IN THE SURVEY
APPENDIX B
INTRODUCTORY LETTER SENT TO RESPONDENTS
APPENDIX C
QUESTIONNAIRE DATA
APPENDIX A

RESULTS OF INITIAL USER REQUIREMENTS SURVEY

Contents

1.0 Sample profile

2.0 Main findings.
   2.1 Independent and chemical representative advisors
   2.2 Whose decision is it?

3.0 Information sources
   3.1 What crop?
   3.2 Planting time
   3.3 Variety Choice
   3.4 Identification and assessment of pests
   3.5 What to spray
   3.6 When to spray
   3.7 Nutrition
   3.8 When to harvest
   3.9 Scheduling work
   3.10 Safety issues
   3.11 Financial issues

4.0 General Issues
   4.1 Observational data
   4.2 Local information
   4.3 Weather data
   4.4 Decision making location
   4.5 The time taken to make decisions
   4.6 Use of computers

5.0 The ideal system
   5.1 Farm data
   5.2 Finance
   5.3 On-line services
   5.4 Databases
   5.5 Advice/utilities
   5.6 System characteristics
1.0 Sample profile

Table 1: Showing cereal acreage of farmers and advisors participating in the study

<table>
<thead>
<tr>
<th></th>
<th>Farmers</th>
<th>Advisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 acres</td>
<td>14,000 acres</td>
<td></td>
</tr>
<tr>
<td>150 acres</td>
<td>8,000 acres</td>
<td></td>
</tr>
<tr>
<td>200 acres</td>
<td>7,000 acres</td>
<td></td>
</tr>
<tr>
<td>244 acres</td>
<td>2,500 acres</td>
<td></td>
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<tr>
<td>280 acres</td>
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<td></td>
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<tr>
<td>425 acres</td>
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<tr>
<td>450 acres</td>
<td>-</td>
<td></td>
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<tr>
<td>500 acres</td>
<td>-</td>
<td></td>
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<tr>
<td>600 acres</td>
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<td></td>
</tr>
<tr>
<td>800 acres</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Showing range of crops covered by farmers and advisors interviewed.

<table>
<thead>
<tr>
<th>Crop</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<th>10</th>
<th>11</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar beet</td>
<td>•</td>
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<tr>
<td>Peas</td>
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<tr>
<td>Oil Seed Rape</td>
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<tr>
<td>Beans</td>
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<td>Barley</td>
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<tr>
<td>Linseed</td>
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<tr>
<td>Grass</td>
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<td>Potatoes</td>
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<tr>
<td>Wheat</td>
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<tr>
<td>Maize</td>
<td>•</td>
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<td>•</td>
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<td>•</td>
<td></td>
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<tr>
<td>Mixed Farms</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
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</tr>
</tbody>
</table>

As tables 1 and 2 above illustrate, a wide variety of farmers and advisors were interviewed during this survey. The acreage of cereals grown ranged from 14 to 800 acres, almost the full crop range was covered by both farmers and advisors and the views of both arable and mixed farmers were included.

2.0 Main findings.

The main findings of the survey are reported below, full details can be found in Appendix C.

2.1 Independent and chemical representative advisors

This survey indicated that the roles of these advisors are almost indistinguishable for our purposes. While the aims of the individuals may vary to the extent that company policy dictates the chemicals/services etc. they recommend to the client,
the aim of all advisors is to provide the client with cost effective advice. The clients continued use of the individuals company will depend on its success in the previous year. The common view expressed by farmers is that chemical representatives and independent advisors cost them roughly the same amount of money, they just extract it in different ways. As the information sources and tools used by both chemical and independent advisors to formulate the advice they provide seem to be essentially the same they are therefore considered to belong to the same user group throughout the remainder of this report.

2.2 Whose decision is it?

The following table indicates the roles played by the farmer and advisor in the decision making process. The title 'advisor' should be taken to include both independent and chemical representative advisors (see previous paragraph).

<table>
<thead>
<tr>
<th>Decision area</th>
<th>Farmer</th>
<th>Advisor (independent &amp; chem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choice of crop</td>
<td>Main role</td>
<td>Confirmation role</td>
</tr>
<tr>
<td>Choice of variety</td>
<td>Main role</td>
<td>Confirmation role</td>
</tr>
<tr>
<td>Cultivation</td>
<td>Main role</td>
<td>Confirmation role</td>
</tr>
<tr>
<td>When to plant</td>
<td>Main role</td>
<td>Only for new varieties</td>
</tr>
<tr>
<td>Field walking</td>
<td>Role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Need for Pest control</td>
<td>Role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Need for Disease control</td>
<td>Role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Need for Weed control</td>
<td>Role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Need for Fertilisers</td>
<td>Strong role</td>
<td>Fertiliser rep has strong role</td>
</tr>
<tr>
<td>Which chemicals</td>
<td>Not strong but role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Spray rate?</td>
<td>Not strong but role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>When to spray?</td>
<td>Main role based on recoms</td>
<td>Role is to state key date</td>
</tr>
<tr>
<td>Safety</td>
<td>Main role</td>
<td>Weak but role varies</td>
</tr>
<tr>
<td>When to harvest</td>
<td>Main role</td>
<td>No role</td>
</tr>
<tr>
<td>Financial decisions</td>
<td>Main role</td>
<td>Role to provide most cost effective solutions</td>
</tr>
</tbody>
</table>

The table above is based on the roles of the average farmer and advisor and should not be taken to cover all cases. The true state of affairs is closer to a continuum model where there is a large overlap in the centre ground of decision making between farmers and advisors (see figure 1). For example some farmers are very scientifically aware and have the time to make their own spray and chemical decisions, others are extremely short of time and find it more effective to leave the bulk of the non-scheduling decisions in the hands of an agronomist.
Figure 1: Showing the roles of farmers and advisors, the overlap between them and the division into scheduling and information based decision types.

This division into scheduling and scientific/information based decisions was seen very clearly in the results of the survey. The farmer has the stronger role in any activity which involves the scheduling of time or resources ie planting, harvesting, when to spray, whilst the advisor plays the strongest role in those activities relating to the application of information based and scientific knowledge ie the need for insecticides, fungicides and herbicides and the best rates of application. The reason for this is that gathering and collating data is a very time consuming and specialised activity and many farmers do not have the time or the expertise to do it effectively.

Decisions to be taken between March and November are particularly susceptible to time pressures; those taken between December and February e.g. variety and market choice are less prone to time pressure and therefore more likely to be carried out mainly by the arable farmer. Mixed farms are of course busy throughout the year and are thus more likely to leave all scientific and information based decisions on their wheat crops to an advisor.

The survey would seem to indicate that the more valuable the crop the more advice the farmer will seek. Where the potential for loss is great, the stress on the farmer is enormous and in many cases it would seem that the advisor also has a 'reassurance' role ie assuring the farmer that the decisions they have taken were the best ones. Trust in the value of the advice is critical, many farmers have known their advisors for years and believe that, on the whole, they are being provided with the best advice possible for their circumstances. It in fact may be necessary for the farmer to
have this level of faith in the advisor, to reduce the burden of stress incurred by high
credit levels and high value crops.

In general it would seem that farmers depend heavily on their consultants for
technical advice, and in some cases this dependence verges on blind faith. Farmers
accept that they cannot keep abreast of all the relevant information themselves and
must therefore accept the help of a third party. This is particularly true in the area of
chemical selection, ie one farmer, who appeared to run an efficient business said

"I find the whole thing increasingly confusing (chemicals) because what they
are doing is issuing the same chemicals but under different names...."

The value of the consultant is judged purely on crop performance, however farmers
can only base their judgements on things that go wrong, they cannot judge whether
an acceptable performance could have been better.

Financial decisions made about the crop are primarily the responsibility of the
farmer, however the advisor also has need of support in this area as their task is to
provide the most cost effective solutions to problems that arise.

3.0 Information sources

The key information sources, ie those mentioned by a majority of respondents, are
discussed below. Problems relating to these sources and identifiable gaps in
provision are also discussed under each of the main decision area headings. A more
detailed description of the data can be found in Appendix C.

3.1 What crop?
The key information input to this decision is the fields position in the rotation cycle.
Where new crops are sought farmers will most commonly refer to market
information (from any available source) and the farming press. Previous experience
and information from advisors and from friends and neighbours is also important.

There were few problems relating to this area, it received a low complexity rating
from both farmers and advisors. Most farmers (7/11) said they didn’t want
additional support to make this decision although some felt that they would like
easier access to market information. Four out of the six advisors were interested in
more assistance.
3.2 Planting time
The farmers own experience is critical to this decision. Advisors do not play a large role. The use of key dates by farmers is common ie plant between September 20th and October 17th and is moderated by knowledge of the variety; field characteristics; soil conditions; the trade off between yield and the probability of disease; machine and personnel availability and seed availability. Knowledge about the weather is also critical.

Once again there were few problems in this area, farmers felt that their own knowledge was generally sufficient. The complexity rating was low for both farmers and advisors. Most farmers (8/11) said they didn't want additional support to make this decision, 4 out of the 6 advisors were interested in more assistance. Timely information on the availability of seed varieties was highlighted as one area that could be improved.

3.3 Variety Choice
Paper based items were most frequently cited as the source of information about crop varieties. The most commonly reported were NIAB and other trial reports, their own field trials, seed company literature and the farming press. The farmer or advisors own experience of the fields characteristics and market requirements are also important. Farmers may also use information on varieties from friends and neighbours.

The complexity rating given by farmers for this decision was higher than for crop choice or planting time and a majority of them (9/11) requested additional support in this area. Five out of six advisors also requested additional support. Timeliness and quantity of information were cited as the main problems. While trial reports were seen as vital, many complained that they didn't receive them until after the decision making period had passed. The difficulty of processing a mass of data from many sources led many to see this an area where computers and databases would be useful.

In addition, the results of crop trials were rarely taken at face value; farmers always looked for confirmation that the results had some relevance to the conditions prevalent on their farm.
3.4 Identification and assessment of:

Weed problems
The nature and extent of the problem is usually determined by observation in the previous year. Sources of information for where to spray are often hand drawn field maps showing the location and density of each weed population.

Recording the location of weeds accurately year by year was seen as the main problem in this area. The introduction of satellite technology and of CD ROM storage were felt by some to be potential solutions.

Insect and disease problems
These two areas have very similar sources of information. They both rely on observation for initial identification and assessment of the level of risk.
Identification relies primarily on the experience of the observer. Assessment of risk requires knowledge of the value of the crop (gross margins), the usual impact of the pest or disease (pest life cycle) and knowledge of the effect of environmental variables such as time of year and current weather patterns on the progress of the pest. Knowledge about the weather is particularly important to the assessment of disease risk.

Field walking is carried out regularly, its frequency ranging from three days to three weeks. The frequency changes based on the time of year and knowledge of potential risk gained from: advisors; farming press; newsletters; forecasts and local information.

The information sources called upon to supply data about pest effects and lifecycles are: past experience; trials data from any source; scientific papers and reports from research establishments and the farming press.

Insect control is generally only used when the pest is seen to be a problem whilst a certain level of fungicide is often applied as a matter of course with additional doses as perceived necessary. The planning of fungicide applications then can to some extent take place prior to the establishment of the crop.

No major problems concerning diagnostic information emerged from this area. While the farmers may not be sure of the nature of a problem they are in general happy to rely on the experience of their advisors. Advisors also have external
sources to call on if their experience fails them and appear to have no need of additional decision support in this area.

Additional forecasting information would however always be welcomed. While existing sources seem to be adequate in transmitting knowledge of pests and diseases when they occur, more detailed information regarding the likelihood of attack would be beneficial. Advisors sometimes find scheduling of field walking in response to a warning problematic. As they are responsible for a large number of fields, they have to determine which are susceptible to the forecast attack and to plan a walking regime which covers the area in the most effective way. As this requires manipulating 'more than a head full' of data, mistakes may occur.

Advisors also have difficulties collating information on new research into pests and diseases from a wide range of sources. Many provide an information service for their clients which involves summarising data of particular interest to them. This is still largely a paper based operation and as such is extremely time consuming.

3.5 What to spray
Knowledge about which chemical is appropriate for a given task is obtained from advisors; notes produced by the chemical manufacturers; chemical company data sheets; advertising; and trial data from any available source. The decision about what to spray is based on this knowledge plus information about the price of the appropriate chemicals, the extent of the problem and the value of the affected crop. In the south particularly, farmers are also likely to consider the environment impact of the chemical and where a choice exists, to choose the least damaging type.

This area was given a high complexity rating by both farmers and advisors and both groups indicated a desire for additional assistance (9/11 farmers; 5/6 advisors). Farmers often said they would like to be able to understand the reasoning behind the choice of chemicals made for them by their advisors. As in previous areas, easier and more timely access to trials information would be useful.

3.6 When to spray
This decision uses information from people based sources. In general the advisor will suggest the optimum spray time and then the actual timing is left to the farmer to arrange, based on scheduling demands. Where contract sprayers are employed, the need to scheduling a range of clients work is a constraining variable.
Spray timing was seen as a complex decision by many of the farmers and by some of the advisors and there was some support for the provision of additional assistance (6/11 farmers and 4/6 advisors said they would like additional assistance).

3.7 Nutrition
Field records and soil tests are the most important sources of information about the condition of the field. Soil tests are usually conducted by the fertiliser companies and advisors; these people will recommend a level of nutritional supplement based on the results of the tests. Fertiplan and Optimix (commercial computer programs) are also used to provide decision support. Additional information sources are: the condition of the crop (observations); the value of the crop and the availability of manure (mixed farms). Satellite information on field health is being used by a number of farms for the first time this year.

The need for information specific to areas of the field were seen as important with regard to nutrition and to yield. The driving force behind this appears to be set-aside and the possibility of taking poor land out of production. The ability to change the rate of nutrition as the sprayer passes over various areas of the field was felt to be useful for both ecological and economic reasons.

3.8 When to harvest
This decision is usually taken by the farmer. Two main factors determine the date, the readiness of the crop (usually indicated by moisture meter or by 'bite') and the weather. While the rule of thumb appears to be 'cut as soon as possible', there is a trade off between the need to be finished before the weather breaks and the desire to cut the costs of drying indoors. Increasing pressure for drier grain from the buyers is making this decision more crucial to the farmers profit margins. Weather forecasts provide an important input to this decision as does knowledge about the availability of people and machinery on the larger farms.

This decision area received a low complexity rating and while advisors requested additional support (4/6), most farmers felt it wasn't necessary (9/11). The main problem reported in this area concerned the local accuracy of weather data: it would appear that any improvements would be welcomed.

3.9 Scheduling work
Scheduling of work is a task which requires mostly human input. The decisions are often difficult to make in advance because of the vagaries of weather and
pest/disease occurrence. The decision area was given a fairly low complexity rating but there was some desire to have additional support provided, 6 out of 11 farmers and 5 out of 6 advisors said they'd like assistance.

Accurate local weather data and support in targeting activities (ie field walking) would be seen as useful.

3.10 Safety issues
Decisions about safety tended to be seen as fairly low input, low priority, particularly on the smaller farms. The key information sources for safety related issues are paper based ie the data sheets supplied with chemicals and the COSHH regulations.

Safety decisions were not generally seen as complex and most farmers said they were not interested in additional assistance (7/11). Four out of the six advisors said they would like assistance and suggested that some method of collating safety data (to enable them to produce reports for their clients) would be welcomed.

3.11 Financial issues
Information necessary to make financial decisions is obtained from many sources, e.g. commercial data, Nix, accountants. On farms the source of information is largely people based; advisors however seem to place a greater emphasis on paper based sources. Many farmers carry out gross margin analysis and they also use information from growers groups and from the farming press. The advisor is expected to provide the farmer with the most cost effective solutions.

This area was considered by most respondents to be highly complex but perhaps surprisingly only 6 out of the 11 farmers requested additional support, in contrast to the 5 out of 6 advisors who felt assistance would be useful. The one financial area where a number of farmers expressed concern was in the choice of chemicals. Farmers are not always sure that they are given the most cost effective advice, particularly where there are vested interests e.g. advice from chemical company representatives. Both growers and advisors complained that there was a shortage of commercial data available to help them make the best choice for their needs.

The inability to integrate information relating to financial matters e.g. for gross margins analysis was seen as a source of frustration by some.
4.0 General Issues

4.1 Observational data
Field walking by the advisor is the primary source of observational data, this is supplemented in most cases by walking by the farmer or farm manager. The frequency of walking depends on the time of year and the perceived level of risk. From once every 3 weeks in the slow season to once every 3 days if there are forecasts of disease.

Advisors would like to be able to access information whilst in the field and to make notes for inclusion into reports for the client. Farmer would also appreciate a handheld tool for note taking or for sketching out weed locations etc.

4.2 Local information
A general impression gained from the interviews was that users feel there is a lack of local information. Knowledge about the experiences of farms in the same geographical area and of local weather and local trial data was seen by many as essential.

4.3 Weather data
The most common sources of weather data are television (Sunday pm particularly), local radio and the met office fax and phone forecasts. A number of farms record their own temperature and rainfall levels.

The lack of accurate and timely local weather data was cited by some as a problem area.

4.4 Decision making location

Table 5: Number of responses to choices in 'where do you make decisions' question

<table>
<thead>
<tr>
<th>Summary</th>
<th>Farmer</th>
<th>Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Office</td>
<td>House</td>
</tr>
<tr>
<td>What to plant</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Planting time</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Crop variety</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Harvesting time</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Scheduling work</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Choosing chemicals</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>When to spray</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Safety Issues</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Financial matters</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>
Planning decisions such as what crop to plant, what variety to use and what chemical vendor and mix to use take place largely in the office or at home, this is also true for financial decisions and for decisions relating to the current weather conditions such as 'can I spray today?'. Field based decisions are generally those which relate to the identification of weeds, pests and diseases and their treatment. The decision to spray is made in the field, as are decisions relating to the type of chemical required and the dosage needed, although preliminary reading will have taken place in the office/home during quieter moments.

### 4.5 The time taken to make decisions

<table>
<thead>
<tr>
<th>Summary</th>
<th>Farmers</th>
<th>Advisors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Imm</td>
<td>Mins</td>
</tr>
<tr>
<td>What to plant</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Planting time</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Crop variety</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Harvesting time</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Scheduling work</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Choosing chemicals</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>When to spray</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Safety issues</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Financial matters</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

Key: i=immediate, m=minutes, h=hours, d=days

The longest decisions to make concern what to plant, what variety to choose, what chemical vendor and mix to select and decisions relating to finance. These are, with one exception, all the information intensive activities. The one area which isn't mentioned is the choice of chemical, most respondents stated that this took minutes-hours, usually while they were standing in the field. It could be argued that in this case the information has already been processed and is available to the farmer or advisor in memory. Decisions as to the timing of planting, harvest and spraying and decisions about the need to spray were all considered to take very little time ie minutes.

### 4.6 Use of computers

While computers were not used by all farmers or advisors, there were a significant number in use (7/11 farmers, 4/6 advisors). Advisors were likely to use them for all aspects of the business ie word processing, accounting, farm management, information storage and retrieval and communication purposes. Farmers however
appear to be using them most often for farm management tasks and information retrieval and storage.

Of those not currently using computers, only 3 stated that they weren't prepared to, one of these people was approaching retirement, the other two felt that they couldn't justify the cost.

5.0 The ideal system

The respondents produced many interesting ideas about the systems they felt would make their lives easier. The ideas which occurred most regularly can be categorised under 5 main headings; farm data; financial tools, on-line services; databases and advice/utilities. These are summarised below:

5.1 Farm data
All farmers who were willing to use computers (see section **) wanted the ability to store farm records. While the method of doing this wasn't specified, the need to be able to keep field maps was stressed. These maps would be linked into other systems such as the satellite system and would enable them to record, display and print out the location and strength of weeds, pests, diseases and nutrition. The crop rotation records would also be kept on disc and may interact with the mapping system.

5.2 Finance
One of the most commonly requested functions was the ability to so 'what if...' scenarios relating to finance. These may be concerned with the costs and impact of fertiliser use, or prophylactic spraying, or the choice of a new seed variety, anything which enables the user to play with possibilities and see the likely outcomes of a decision before actually taking it would be seen as useful.

The ideal system would incorporate the cost analysis system they currently use but allow it to 'talk' to and use input from other sources of information. Failing that a simple means of transferring their existing data to a new format would be required.

Several people requested a computer version of the Nix handbook.
5.3 On-line services
The term 'on-line' in this context does not refer specifically to a service called up by the user, many users felt the costs of many such services were prohibitive and unnecessary and that they were too time consuming to use. On-line refers to any service which is not located on the users premises ie dial-up services and those which send information to the user on a daily or weekly basis either via the computer or via a fax machine.

Information which the users would like to access by this means are chemical prices, market prices, local weather forecasts, chemical availability, seed availability and disease and pest forecasts.

The need to find out what was going on locally could be fulfilled by use of a 'bulletin board' to which farmers and advisors could contribute.

5.4 Databases
These would ideally be disc or CD based and permit easy searching on key-words and facilities to copy information to other files for collating, sorting etc. Users requested databases of trials results, journal abstracts, press reports, other research information, chemical data and prices and safety data.

5.5 Advice/utilities
This category brings together all the tools which provide access to scientific knowledge, either in the form of guides e.g. a disease/pest diagnosis programs using photographs on CD ROM, or 'what if...' simulation tools. While this type of system was seen as desirable the point was often made that the reasoning behind advice should be transparent, that no trust would be placed in systems which simply 'gave the answers'.

The scheduling support tool also sits under this heading, if a little uncomfortably. It would be required to support the farmer in scheduling farm jobs to make the best use of people and machines and also to support the advisor in scheduling their farm visits. It would have to be capable of re-evaluating its advice on the basis of other data such as weather or disease forecasts.
5.6 System characteristics

The ideal system for both farmer and advisors will be portable and include communication functions. Advisors need something they can work on in the office, in the field and at home without having to constantly transfer material from one machine to another. The ability to 'phone' into the office and pick up new information or query office databases is also required. Farmers too spend almost as much time working on farm business at home as they do in the farm office and will need to be able to keep the same information in both places. A built in fax and printer were suggested by many as desirable. The 'ideal' system would perhaps look something like this:

For ergonomic reasons it is not advisable to use the portables screen and keyboard for long periods and so for office use a larger screen and full keyboard are required. To avoid problems associated with the transfer of data, these items could be plugged into the portable as external devices, leaving the portable to act as the 'hard disc'.

For field use a pen based notebook would be most useful, allowing rough sketching and form filling activities to take place. These files could then be downloaded into the portable for incorporation into farm records, customer reports etc.
TEXT BOUND INTO

THE SPINE
### 1. Nature of job in relation to the crop

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>All decisions</td>
</tr>
<tr>
<td>G2</td>
<td>All decisions</td>
</tr>
<tr>
<td>G3</td>
<td>All decisions</td>
</tr>
<tr>
<td>G4</td>
<td>All decisions</td>
</tr>
<tr>
<td>G5</td>
<td>All decisions</td>
</tr>
<tr>
<td>G6</td>
<td>Assistant manager - so input to most decisions</td>
</tr>
<tr>
<td>G7</td>
<td>All decisions</td>
</tr>
<tr>
<td>G8</td>
<td>All decisions</td>
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<tr>
<td>G9</td>
<td>All decisions</td>
</tr>
<tr>
<td>G10</td>
<td>All decisions</td>
</tr>
<tr>
<td>G11</td>
<td>Manager - so responsibility for most decisions</td>
</tr>
<tr>
<td>R1</td>
<td>Sales manager but also advises on all aspects to small number growers</td>
</tr>
<tr>
<td>R2</td>
<td>Advises farmer on all aspects of crop depending on need</td>
</tr>
<tr>
<td>A1</td>
<td>Advises farmer on all aspects of crop production</td>
</tr>
<tr>
<td>A2</td>
<td>Advises farmer on all aspects of crop depending on need</td>
</tr>
<tr>
<td>A3</td>
<td>Advises farmer on all aspects of crop production</td>
</tr>
<tr>
<td>A4</td>
<td>Advises farmer on all aspects of crop production</td>
</tr>
</tbody>
</table>

### 2. Area of cereals grown/looked after

<table>
<thead>
<tr>
<th></th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>800 acres</td>
</tr>
<tr>
<td>G2</td>
<td>200 acres</td>
</tr>
<tr>
<td>G3</td>
<td>600 acres</td>
</tr>
<tr>
<td>G4</td>
<td>280 acres</td>
</tr>
<tr>
<td>G5</td>
<td>500 acres</td>
</tr>
<tr>
<td>G6</td>
<td>450 acres</td>
</tr>
<tr>
<td>G7</td>
<td>150 acres</td>
</tr>
<tr>
<td>G8</td>
<td>150 acres</td>
</tr>
<tr>
<td>G9</td>
<td>244 acres</td>
</tr>
<tr>
<td>G10</td>
<td>14 acres</td>
</tr>
<tr>
<td>G11</td>
<td>425 acres</td>
</tr>
<tr>
<td>R1</td>
<td>2,500 acres</td>
</tr>
<tr>
<td>R2</td>
<td>7,000 acres</td>
</tr>
<tr>
<td>A1</td>
<td>8,000 acres</td>
</tr>
<tr>
<td>A2</td>
<td>14,000 acres</td>
</tr>
<tr>
<td>A3</td>
<td>-</td>
</tr>
<tr>
<td>A4</td>
<td>-</td>
</tr>
</tbody>
</table>
Text cut off in original
### List of crops grown

<table>
<thead>
<tr>
<th>Crop</th>
<th>Farmers</th>
<th>Advisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar beet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil Seed Rape</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inseed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed Farms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Complexity. (If 5 is 'very complex' and 1 is 'not at all complex')

<table>
<thead>
<tr>
<th>What to plant</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
<th>G6</th>
<th>G7</th>
<th>G8</th>
<th>G9</th>
<th>G10</th>
<th>Al</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>R1</th>
<th>R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting time</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop variety</td>
<td>3</td>
<td>3/4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Harvesting time</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>5</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Scheduling work</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
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<td>-</td>
<td>-</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Choosing chemicals</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>1</td>
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<td>3</td>
<td>3</td>
<td>4</td>
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<tr>
<td>When to spray</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
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<td>3</td>
<td>3</td>
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<td>3</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td></td>
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<tr>
<td>Safety Issues</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>4</td>
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<td>5</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Financial matters</td>
<td>3/4</td>
<td>2/3</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>5</td>
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5. Where do you obtain assistance when making each of these decisions? From people, paper based sources (books, papers, magazines, pamphlets etc.) or computer based sources?

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Would you like to have easier access to assistance in making any of these decisions?

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7. Generally where do you make these decisions, in the farm office, in the house, in the field or a combination?

Key: o = office, f = field, h = home

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3. How long does it take to make these decisions? Immediately, minutes, hours, days?

Key: i=immediate, m=minutes, h=hours, d=days

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Key: i=immediate, m=minutes, h=hours, d=days
9. Do you use a computer for the following (A)? Would you be prepared to (B)?

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*teletext only

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Summary - are using these facilities

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4. Where do you think the bottlenecks are in the decision making process? Can you think of anything which might improve your ability to make accurate decisions?

- More background information, more knowledge, more experience. Bottlenecks are time pressures.
- Better crop recording (own data) - much easier budgeting on a computer. Costs analysis is a bottleneck - long time to work out on &.
- Better memory. Satellite based fertiliser system. System for deciding on sprays etc. - but all too expensive. Access to more knowledge. Most important is accurate weather forecasting for the next week. CAP/government interference removed from the decision process.

5. If you could design a system just for you what features would you include and what problems would you use it for?

- Would incorporate all individual weed/disease responses for each and every chemical approved for that crop, plus responses to part doses. Chemical costings so that could work out the most economical answer. Link this into the print-out for the spray person. Link it into the gross margins analysis system - so that when the spraying had been carried out you'd have the costs. Read out onto a smart card to go in the sprayer for differential spraying with the option of satellite control for patch spraying. Would also like a database which stores all the information from the technical meetings so could access quickly by keyword. Scientific & abstracts would also be useful.

- She would like a lap top, printer and fax all built in plus a pen input device so she could write on the screen. Up-to-date information on crop trials, opinions, commercial information. Easy access to trials data, commercial and manufacturing information. The ability to store her own technical information. To be able to communicate with others, colleagues and clients. Access crop records. On-line facility to get data updated. A reporting package so could easily draw together facets of the information to produce reports. Decision support modules. Compatibility with other machines. Easy to use or good training support.
He takes photographs to remind himself of the weed situation in the previous year - he forgets otherwise. He would like to be able to store these on disc so he can remind himself and draw up maps of where the weeds occur (pictures of fields and coloured patches to indicate weed type and extent). He would like to have a little hand held computer notepad so he could draw in the patches as he walks around the fields. Would love to be identify all the soil types across the fields - using a strain gauge perhaps so he could see where the patches were.

What you need for mapping is not to much GPS but a contour system. If give someone a map and point out a spot on the field chances are that it will be pretty meaningless in the field whereas if you use contours (3D) so could translate to real location. Need a human system - so can translate reference to 'third terrace' up. Big fields don't have real landmarks. Could get the satellite information on location then translate that for the ordinary man with the knapsack whose got to go and do the Job and doesn't need a computer strapped to his back as well.

Disease forecasting systems would b good and access to all blackgrass trials with the associated weather data. database of keyworded trials.

Field mapping - where the weed problems are, soil type and everything else - sees as a picture on the screen - map outline. fertiliser recommendations - how much to put on when - linked with satellite. Store all detailed information for each field. gross yields margin display - each area of field - how its doing. chemical information database. Access to market and weather information would be very useful.

System which would tie into the field mapping, plot profitability of each field. system which enables you to retrieve information easily - simple, user friendly crop management system. if you were doing it this way you would look at your cropping plans a little differently. It might change rotation or crops selected. Biggest chore is putting info in, easier method - talk to it? In the office or while walking round fields, e.g spray X on field y - computer would sort it out, bring up costs based on chemical used, work it all out. Also have accounts on it. Anything which helps sort out how to make the best use of the soil given new CEC regulations etc. and still leave it in good heart. Cost predictions. No computer can tell you when the soil is ready for drilling or anything like that, that's his Job.

Fungicide - tell exactly what diseases were on plants, how critical they are in terms of money to eradicate and how to do it. Fertilisers what and where - satellite system. Slugs and aphids monitor (with garden supplement).

NIAB lists, gross margin information, John Nix farm pocket book information, all the background trials, charts diagrams, lots of graphical presentations.
16. Checklists (make sure no information source etc. is forgotten and use to prompt)

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16. Checklists (make sure no information source etc. is forgotten and use to prompt)

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<td>Own Weather Records</td>
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<td>Previous Experience (what rules of thumb do they use?)</td>
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Factors considered when deciding upon treatment regime

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<tr>
<th>Factors</th>
<th>g1</th>
<th>g2</th>
<th>Probed</th>
<th>Prompted</th>
<th>Not mention</th>
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<tr>
<td>Observation Of Crop</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Growth Rate</td>
<td>-</td>
<td>+</td>
<td></td>
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<tr>
<td>Work Load (Other Jobs On Farm)</td>
<td>+</td>
<td>+</td>
<td></td>
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<td>Weather Conditions</td>
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<tr>
<td>Machine Availability</td>
<td>-</td>
<td>+</td>
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<td>Disease Susceptibility (Variety)</td>
<td>+</td>
<td>+</td>
<td></td>
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<td>Field History</td>
<td>+</td>
<td>+</td>
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<td>Neighbouring Crops</td>
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<td>+</td>
<td></td>
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<tr>
<td>Value Of Crop</td>
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<td>+</td>
<td></td>
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<tr>
<td>Cost Of Treatment</td>
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<tr>
<td>Level Of Risk</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Available Chemicals</td>
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<td>+</td>
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<td>COSHH, H&amp;S Issues</td>
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<td>Legislation</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Growth Stage/Time Of Year</td>
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POSTAL QUESTIONNAIRE DATA - SUMMARY OF RESULTS

OCCUPATION OF SAMPLE

Approximately 200 questionnaires were distributed to brassica growers during January and February 1994. A total of 78 people replied, which can be considered a good response for this type of survey. Seventy-two of the 78 respondents described themselves as 'growers', 1 as a consultant the rest as 'commercial', 'co-op' or 'consortia'. Although the questionnaire were anonymously returned an examination of the legible postmarks showed that most key growing areas were represented, figure * below illustrates the pattern of returns.

Fig 1 here - change other fig numbers

COMPUTER USAGE

Two thirds of those who responded own a computer, most of which are IBM or IBM clones (83% of all computers). Of the 48 systems with known operating systems 70% were Dos based machines and 60% were also capable of running Windows (see Fig.1). The majority of computers have colour screens (85%), hard discs (96%) and use a mouse (76%). Of the 46 who answered the printer question, the majority (34) use dot matrix printers, a further 6, inkjet machines and 3, laser printers.

<table>
<thead>
<tr>
<th>Frequency Distribution for O/S</th>
<th>Count</th>
<th>Percent</th>
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<td>1.923</td>
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<tr>
<td>Dos</td>
<td>16</td>
<td>30.769</td>
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<td>Windows</td>
<td>10</td>
<td>19.231</td>
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<td>Windows/Dos</td>
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<td>Unknown</td>
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<td>7.692</td>
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<tr>
<td>Total</td>
<td>52</td>
<td>100.000</td>
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</table>

The questionnaire asked people what things they used their computer for based on a tick list of 16 items. The most common uses were accounting (86%), word processing (82%), farm/field records (59%), stock records (57%), management (45%) and presentation materials (30%). Approximately a quarter of respondents also use their computers for staff/labour planning (24.5%), general crop scheduling (22%) and planting (24.5%). Other uses include spray planning (14%), client databases (12%), modelling (12%) and crop maturity prediction (10%).
Management Software
Of the 24 people who answered the question about management software 15 said they used proprietary software eg 'Optomix', 'Farmplan' and 8 their own 'customised' software or spreadsheets.

Who are the users?
Almost half of the 33 responding to this question said they used the software themselves (45%), 24% said others used it and 24% that they and others used the system. Of the 'others' involved 12% said senior staff and secretaries and another 6% office staff.

THOSE NOT USING COMPUTERS
Twelve of the 26 people who said they did not currently own a computer are thinking of getting one in the future for management purposes, interest, integration with other technology or in response to parent company demands. Five of the 26 said they would not be getting one; financial or no justification were the reasons given. Nine people didn't answer this question.

Eighty-one percent of the people who do not currently own computers said they would find paper based forecasts useful.

METEOROLOGICAL DATA
Almost two thirds of the sample population make use of meteorological data (64%); 76% of those who do collect their own data and 44% use information from the local Meteorological station.
<table>
<thead>
<tr>
<th>Data type</th>
<th>No. out of (38)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>31</td>
<td>81</td>
</tr>
<tr>
<td>Min/max</td>
<td>15</td>
<td>39</td>
</tr>
<tr>
<td>Windspeed</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>Temp</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Solar radiation</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Wind direction</td>
<td>2</td>
<td>5</td>
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<tr>
<td>Pressure</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Soil temp</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Solar weather action (PCWS)</td>
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<td>2</td>
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<tr>
<td>Moon cycles</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sun &amp; shade</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 1: Showing the types of data collected by respondents.

The most common type of data collected by respondents is rainfall (81%) and min/max temperatures (39%); however windspeed and daily temperature are gathered by a significant minority (21% and 18% respectively). Other measures such as air pressure, wind direction, solar radiation, solar weather action, sun/shade or moon cycles are gathered by less than 5% of those responding.

<table>
<thead>
<tr>
<th>Data type</th>
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</thead>
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<tr>
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<td>40</td>
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<tr>
<td>rainfall</td>
<td>12</td>
<td>54</td>
</tr>
<tr>
<td>windspeed</td>
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<td>36</td>
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<tr>
<td>wind direction</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>frost</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>sunshine hours</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>solar radiation</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2: Showing types of data collected from the met. office.

Of those who use Met Station information 54% said they used rainfall data, 40% temperature (including min/max temperature) and 36% windspeed data; less than 5% reported using wind direction, frost, sunshine hours or solar radiation.

Eleven out of the 14 people who answered the question said that they would consider getting their own weather station. Some of the circumstances considered necessary to the purchase were 'if the cost could be justified', 'they were automatic' or if 'Met Station data was unavailable'.

Ten out of the 22 people who said they used meteorological data also said they were happy to adjust it to local conditions, 3 were not always happy to do so; 9 did not answer the question.

Ninety-five percent of the 61 people who answered the question said they made use of weather forecasts.
DECISION SUPPORT TOOLS

<table>
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<th>Subject</th>
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</thead>
<tbody>
<tr>
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<td>20</td>
<td>25.64</td>
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<tr>
<td>Crop readiness</td>
<td>26</td>
<td>33.33</td>
</tr>
<tr>
<td>Spacing</td>
<td>22</td>
<td>28.21</td>
</tr>
<tr>
<td>Irrigation</td>
<td>26</td>
<td>33.33</td>
</tr>
<tr>
<td>Pests</td>
<td>61</td>
<td>78.21</td>
</tr>
<tr>
<td>Diseases</td>
<td>52</td>
<td>66.67</td>
</tr>
<tr>
<td>Nutrition</td>
<td>40</td>
<td>51.28</td>
</tr>
</tbody>
</table>

| Table 3: Showing the type of decision support tools respondents suggested they would find useful. |

**General:** Over three quarters of the sample (78%) indicated that they would find useful some form of prediction or forecasting system concerned with pests, two thirds said they would like one concerned with diseases (67%) and around a half (51%) would like one concerned with nutrition. Other decision support systems received less support with around a third of respondents looking for support in predicting crop readiness (33%) and planning irrigation requirements (33%) and around a quarter who felt help making crop scheduling and crop spacing decisions would be useful (26% and 28% respectively).

**Pests:** When asked which pest forecasts would be most useful 57% out of the 61 who responded to the question said cabbage root fly, a further 18% carrot root fly; 49% brassica related aphids such as mealy and cabbage aphid; 11.5% caterpillars eg. diamond back moth and small white butterfly. Forecasting systems concerned with cutworm, pollen beetle and slugs were requested by less than 5% of the respondents.

**Diseases:** A wide variety of disease forecasting systems were requested by the 52 people who felt this type of decision support system would be useful (see Appendix A). Respondants appear to want systems to forecast the appearance of spot producing diseases of which the most important appear to be Alternaria (15%), Ring Spot (11.5%) and White Blister (11.5%). Systems for forecasting Mildews also seem to be required, most of the requests were not specified but 7% wanted Downy Mildew and 2% Powdery Mildew. A forecasting system for Botrytis was requested by 13% of those responding.

**Minerals:** Of the 40 people who requested decision support tools concerned with minerals 32 (80%) were interested in Nitrogen, 32% Phosphate and Pottassium, 27.5% Magnesium, 10% Calcium and 5% Sulphur. Trace elements were also seen as important with 22.5% interested in Manganese, 10% in Boron and 5% in Copper. No-one expressed a specific interest in Iron or Molybdenum.

**SOURCES OF INFORMATION**
Seventy two people provided details about their current sources of information. A wide variety of sources were quoted (see Appendix A) the most frequent of which were ADAS (46%) private consultants (21%), chemical companies (18%), in-house expertise and experience (15%), HDC (13%) and HRI (11%).
APPENDIX D:
DESSAC Second Phase User Requirements Survey


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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Second user requirements survey and summary of results.

Document UNG/2.0
(Revised Section 4.0)

Decision processes for winter wheat.
User requirements for future decision support systems.

January 1994

Authors:
Caroline Parker, HUSAT Research Institute
Peter Janes, ADAS Ergonomics Unit
Paul Mrozowski, ADAS Ergonomics Unit
Robert Cook, Morley Research Institute
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   2.2 Users
   2.3 Sample size and selection
   2.4 Materials
   2.5 Procedure

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      3.2.2 Sources of agronomic advice
      3.2.3 The role of the adviser
      3.2.4 Whose decision is it?
      3.2.5 Factors and information sources
      3.2.6 Observational data
      3.2.7 Local information
      3.2.8 Weather data
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APPENDIX A: Questionnaire used in the survey
APPENDIX B: Scenarios
EXECUTIVE SUMMARY

During 1993 and early 1994 discussions between MAFF, HGCA, crop agronomists, researchers and representatives from the agrochemical industry, developed a series of ideas on arable crop decision support systems (DSS). These ideas in the form of a project proposal have since been accepted as part of the MAFF Link programme on technologies for sustainable agriculture. In view of the ambitious nature of this project and the need to establish clear user requirement baselines, MAFF provided funds for some preliminary work into the determination of the user requirements.

Two sets of interviews have taken place to date; the first in September and October of 1994 and the second in November and December of the same year. The methodology and results of the first stage is described in document UNG 1.0. While the current report describes the methodology employed in the second stage (Section 2.0) its main purpose is to summarise the findings of both surveys (Section 3.0) and present a clear picture of the user requirements for arable crop decision support systems (Section 4.0).

The purpose of this survey to extend and validate the findings from the first set of interviews has been accomplished and the results summarised here are based on a sample of 32 farmers, with farm sizes ranging from 14 to 1150 acres of cereal; and 12 advisers with cereal coverage of between 2,500 and 14,000 acres.

The main users of the proposed systems are likely to be advisers and farm managers. The facilities which are conceivably of the greatest value to advisers are: the ability to access local and remote databases; the ability to manipulate database contents; the ability to incorporate their findings into other documents; and the ability to access compiled scientific data. Facilities which may be of equal use to advisers and farm managers are those which support the recording of farm data and those which support financial calculations and financial 'what if's.'

The conclusion of the report is that the development of an integration framework is vital. The ability to bring together information from a variety of sources is required for users, particularly advisers, to move from paper based to computer based methods. The integration of materials also forms a large part of the work of the advisers.

The validity of these findings will be further tested by users in a series of workshops to be held in March 1995.
1.0 INTRODUCTION

During 1993 and early 1994 discussions between MAFF, HGCA, crop agronomists and researchers, as well as representatives from the agrochemical industry, developed a series of ideas on arable crop decision support systems (DSS). These culminated in the establishment of a steering group early in 1994 to formulate a project proposal. This proposal, supported by MAFF and the HGCA Research and Development committee, has since been accepted as part of the MAFF Link programme on technologies for sustainable agriculture.

In view of the ambitious nature of this project and the need to establish clear user requirement baselines, MAFF provided funds to allow some preliminary work to take place during the current financial year ending in March 1995. This support has enabled the first phase of the determination of the user requirements to be undertaken.

In September and October of 1994 initial interviews with two discrete groups of potential users took place. These interviews were designed to identify their information needs, the sources of their information, and the interactions between the decisions in arable crop production on the individual farms. The results of this research were reported to the User Group on the 26th October 1994 and presented in UNG 1.0.

Whilst the findings from the first stage were considered to be interesting the size of the user sample was seen, by the Group, to be inadequate given the importance of the research as a foundation for the forthcoming Link project. The acreage of the farms in the sample was also felt to be too small to be truly representative.

In the light of these comments second and third requirements analysis stages were planned. The second, consisting of a further set of interviews, is reported here and collated with findings from the first survey. The third stage will consist of a series of workshops for representative users and is discussed further in the last chapter of this report.
2.0 METHOD

2.1 Design
The purpose of this survey was to validate and expand the user requirements identified in the first set of interviews, that is to: further examine the decision processes relating to arable crops; the areas in which decision support systems might be of particular relevance to users; and the type of information they currently use.

2.2 Users
As in the previous study three main classes of users - farmers, chemical representatives and independent advisers - were identified. Chemical representatives and independent advisers were considered to be different user groups as they were seen to have different objectives and thus potentially different requirements.

2.3 Sample size and selection
Names and addresses of farmers were selected from a list provided by the ADAS Ergonomics Unit; advisers contact addresses were selected from the Association of Independent Crop Consultants 'Directory of Members' and the Yellow Pages. Farms under 100 acres were not considered. An additional form of selection occurred prior to interview as many of those contacted were unable to make themselves available, time constraints being the most frequently cited cause.

To make best use of the geographic location of the investigating partners HUSAT concentrated its efforts on the North and Midlands counties, whilst ADAS Ergonomics focused on the South. To provide a more representative sample the interviews focused on different counties from the previous set i.e. North Yorkshire, Norfolk, Lincolnshire, Leicestershire, Wiltshire, Hampshire & Avon. A total of 21 farmers, 4 advisers and 2 chemical representatives were interviewed over a period of three weeks during December 1994.

2.4 Materials
The interviews were structured and standardised by means of a questionnaire and scenarios.

The questionnaire covered many of the same topics as the previous survey. However it was devised to ensure that all the topics considered important to the
validation of the user requirement were covered e.g. source of information, roles of farmer and adviser, use of computer; and where appropriate to permit finer detail to be elicited.

While the questionnaire was designed to extract information on the existing situation and on the information needs as currently perceived by the users, an additional validation tool, the scenario, was employed to provide feedback on our suggestions for future implementations of their ideas. The scenario is a story like description of the proposed systems in use in a situation familiar to the users. Four scenarios were devised and from these three were chosen for use in the interviews; two for farmers and one for advisers. Copies of the questionnaire and the scenarios are provided in Appendices A and B respectively.

All interviews were recorded with the permission of the interviewee.

2.5 Procedure
Individuals from the user groups were contacted by telephone by either HUSAT or ADAS Ergonomics. The nature of the project and the purpose of the interviews was explained; and where the user was agreeable interview dates were organised.

At the start of the interview the respondent was given background information on the project work being undertaken. The interview took place in two parts. In the first part the respondent was taken through the questionnaire and in the second they were asked to comment on the scenario.

Farmers were asked to state the area of arable crops and winter wheat they grew. Advisers were asked to identify the area they provided advice on and the number of farms they were responsible for. Interviewees were then asked about their use of computers for word processing, accounting, farm management, information storage and retrieval and communication purposes; and their willingness to employ them in the future if they did not already do so. They were then asked to describe the information they currently recorded e.g. yields, spray records etc.

The questionnaire contained a list of decision areas derived from the previous set of interviews. Users were asked to look at each of these areas in turn and to state who was responsible for the decision: themselves, 'others' or 'mixed' i.e. taken jointly with others. When 'mixed' was chosen they were asked to expand and describe the parts
of the decision taken by each contributor: when 'other' they were asked who the 'other' person was.

The interviewer then reviewed each of the main and 'sub' decision areas (parts of the mixed decision) for which the user had sole responsibility. In each case the user was asked to describe the factors that they felt were important in making the decision e.g. soil type, weather; the source they used to obtain information about these factors; and the ease with which they could access these sources.

Where time permitted additional questions were put to the user on each of the areas they had responsibility for i.e: what confidence they had in making the decision and in staying up to date with the information; the length of time it took to absorb the information and to make the decision; the urgency of the decision; and the extent to which the users own experience was necessary.

On completion of the questionnaire users were asked to read the scenario they were given and to make comments as to the accuracy with which the story reflected their own working experience and their feelings about the technology it described.
3.0 RESULTS

3.1 Sample profile

<table>
<thead>
<tr>
<th>Cereals (acres)</th>
<th>Winter wheat (acres)</th>
<th>Cereals (acres)</th>
<th>Winter wheat (acres)</th>
<th>Cereals (acres)</th>
<th>No of farms</th>
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<td>90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>490</td>
<td>140</td>
<td></td>
<td>120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>460</td>
<td>80</td>
<td></td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>427</td>
<td>427</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As table 1 illustrates; a range of farms are represented in the sample. The farms produce an average of 440 acres of cereal and an average of 280 acres of winter wheat. The advisers are responsible for an average of 6000 acres over 30 farms.

Taking the two surveys together, 32 farmers have been interviewed to date, with farm sizes ranging from 14 to 1150 acres of cereal. Twelve advisers have also been seen, comprising 2 ADAS, 4 chemical company representatives and 6 independents, with cereal coverage ranging from 2,500 acres to 14,000 acres.

3.2 Main findings.

The main findings of the combined survey are reported below.

3.2.1 Use of computers

Only a third of the farmers in this survey are currently using computers, in comparison to two thirds of the sample in the previous research. This does not mean that this sample are less interested in computers however, as another third are thinking of using them in the near future. It would seem that those who are not interested in the technology tend to be older farmers and those from smaller farms where the effort required to use a computer is not justified by the benefits they can bring. In contrast to the previous study this sample of farmers employ computers for a broad range of uses ie for word-processing, accounting, farm-management and information storage. The previous research suggested that the uses were largely confined to information storage and farm management. Half of the farmer sample were also interested in using their computers for communication purposes.

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Three out of the six advisers in this sample are current computer users and the other three said they would be using them in the future for one purpose or another. Advisers were again interested in the broad range of computer uses but particularly in farm management, information storage and communication.

### 3.2.2 Sources of agronomic advice

The previous study indicated that the roles of the Independent and chemical representative advisers are almost indistinguishable for our purposes. The results of the present survey do not alter this view. While the aims of the individuals may vary to the extent that company policy dictates the chemicals/services etc. they recommend to the client, the aim of all advisers is to provide the client with cost effective advice. The information sources and tools used by both chemical and independent advisers seems to be essentially the same; although it does seem that the independent advisers have more difficulty obtaining it. Independent and chemical company representatives are considered to belong to the same user group throughout the remainder of this report.

During this research it became apparent that other sources of advice were sometimes used by farmers, most notably from grain buyers. The project does not currently have any information regarding these potential users.

### 3.2.3 The role of the adviser

The role of the adviser was examined more closely in this survey. In general the findings of the previous research were confirmed: in fact the perception that farms have a need for the role of the adviser has been strengthened. The main points are given below.

It would seem that farmers, in general, depend heavily on their consultants for technical advice: in some cases this dependence seems to verge on blind faith. Farmers accept that they cannot keep abreast of all the relevant information themselves and must therefore accept the help of a third party. This is particularly true in the area of chemical selection.

The more valuable the crop the more advice the farmer will seek. One reason for this may be that where the potential for loss is great, the stress on the farmer is enormous and any means of reducing the burden will be sought. The use of an adviser is seen as a means of shedding some of the responsibility for areas in which
the farmer is less confident. This is also reflected in farmers' use of advisers for second opinions on those decision areas which are not really in the adviser's remit, e.g., choice of farm machinery. The value of this 'reassurance' role should not be underestimated.

Trust in the value of the advice is critical to this relationship. Many farmers have known their advisers for many years and believe that, on the whole, they are being provided with the best advice possible for their circumstances. They have no real means of judging the quality of this advice other than the performance of the crop. However, it would appear that even when crops do perform badly, other variables, such as the weather, are blamed rather than the judgement of the adviser. It is also true that farmers can only base their judgements on things that go wrong; their only means of judging whether an acceptable performance could have been better is to monitor the performance of their neighbours' crops.

The reasons for this lack of criticism from a generally astute population may be other than necessary faith in an associate of long standing. It also seems to be the case that many farmers do not follow their advisers' advice to the letter; they may increase or reduce the rates of chemicals; or use machinery which does not reliably spray at the prescribed rate. The seeming reluctance to blame the adviser for poor yields may also be due to their knowledge that their actions may be part of the cause.

Not all farmers have long-standing relationships with their advisers; however, and the points above are not likely to be true for all cases. Situations where farms have changed hands or where two farms merge but maintain two advisers provide opportunity for competition.

3.2.4 Whose decision is it?

The following table (table 3) illustrates the roles played by the farmer and adviser in the decision-making process. However, it is based on the roles of the average farmer and adviser, the true state of affairs is closer to a continuum model where there is a large overlap in the centre ground of decision-making between farmers and advisers (see figures 1 and 2). For example, some farmers are very scientifically aware and have the time to make their own spray and chemical decisions, others are extremely short of time and find it more effective to leave the bulk of the non-scheduling decisions in the hands of an agronomist.
Table 3: Showing the roles played in general by the farmer and adviser

<table>
<thead>
<tr>
<th>Decision area</th>
<th>Farmer</th>
<th>Adviser (independent &amp; chem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choice of crop</td>
<td>Main role</td>
<td>Confirmation role</td>
</tr>
<tr>
<td>Choice of variety</td>
<td>Main role</td>
<td>Confirmation role</td>
</tr>
<tr>
<td>Cultivation</td>
<td>Main role</td>
<td>Confirmation role</td>
</tr>
<tr>
<td>When to plant</td>
<td>Main role</td>
<td>Only for new varieties</td>
</tr>
<tr>
<td>Field walking</td>
<td>Role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Diagnosis of pests &amp; diseases</td>
<td>Role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Need for Weed control</td>
<td>Role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Need for Fertilisers</td>
<td>Strong role</td>
<td>Fertiliser rep has strong role</td>
</tr>
<tr>
<td>Which chemicals/rate</td>
<td>Not strong but role varies</td>
<td>Main role</td>
</tr>
<tr>
<td>Which supplier</td>
<td>Role varies</td>
<td>Role varies often are supplier</td>
</tr>
<tr>
<td>When to spray?</td>
<td>Scheduling role based on recoms</td>
<td>Role is to state key date</td>
</tr>
<tr>
<td>Safety</td>
<td>Main role</td>
<td>Weak but role varies</td>
</tr>
<tr>
<td>When to harvest</td>
<td>Main role</td>
<td>No role</td>
</tr>
<tr>
<td>Financial decisions</td>
<td>Main role</td>
<td>Role to provide most cost effective solutions</td>
</tr>
</tbody>
</table>

Figure 1 shows the distribution of responsibility as suggested by the respondents in the most recent survey. Figure 2 provides an combined view of the scheduling/information split.
User requirements for decision support systems
UNG/2.0

<table>
<thead>
<tr>
<th>User</th>
<th>Farmer</th>
<th>Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;&lt; May be either &gt;&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Decision Area</th>
<th>Farmer</th>
<th>Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling schedule</td>
<td>Optimum spray date</td>
<td></td>
</tr>
<tr>
<td>Variety choice</td>
<td>Optimum drilling date</td>
<td></td>
</tr>
<tr>
<td>Spray scheduling</td>
<td>Extent of the problem</td>
<td></td>
</tr>
<tr>
<td>Harvesting time</td>
<td>Diagnosis</td>
<td></td>
</tr>
<tr>
<td>What crop to plant</td>
<td>Spray rate</td>
<td></td>
</tr>
<tr>
<td>What markets</td>
<td>What to spray</td>
<td></td>
</tr>
<tr>
<td>Cultivation</td>
<td>Chemical vendor</td>
<td></td>
</tr>
<tr>
<td>Farm work scheduling</td>
<td>Safety</td>
<td></td>
</tr>
</tbody>
</table>

Decision Type
- Scheduling decisions
- Scientific & Information based decisions

![Figure 2: Showing the roles of farmers and advisers, the overlap between them and the division into scheduling and information based decision types.](image)

The farmer has the stronger role in any activity which involves the scheduling of time or resources e.g. planting, harvesting. The adviser plays the strongest role in those activities relating to the application of information based and scientific knowledge: ie the need for insecticides, fungicides and herbicides and the best rates of application. This is true even where the division of responsibilities seems to be mixed e.g. 'when to spray' or 'safety'. The reason for this is that gathering and collating data is a time consuming and specialised activity and many farmers do not have the time or the expertise to do it effectively. The exceptions to this rule are 'what markets' and 'variety choice' and it would seem that these decisions are taken when farmers have more free time on their hands i.e. in winter or pre-harvest.

3.2.5 Factors and information sources
The key factors considered when making winter wheat decisions and the sources of information used are described below. Problems relating to these sources and gaps in provision are discussed under each of the main decision area headings.

What crop?
The key information inputs to this decision are:
- market values
- the fields position in the rotation cycle.
- needs of farm stock
- gross margins
- need for specialist machinery
- knowledge of the fields capabilities
As the list indicates much of the decision is based on the farmers own experience and knowledge of the farm. However the external information sources used to make this decision are: the farming press; ADAS; advisers; financial advisers; and from friends and neighbours.

Two areas are of potential interest to the project. The need for better access to market information and the need for knowledge of crop performance in the immediate locality; both of which would be of interest to farmers and many advisers.

**Planting time**
The factors key to this decision are:
- weather (soil conditions)
- variety
- field characteristics
- previous crop (availability of the field)
- strategy (early or late)
- machine and personnel availability
- seed availability
- key dates (e.g. between Sept. 20th and Oct. 17th)

The farmers own experience is critical to this decision. Advisers do not often play a large role although they may give the farmer a date to start from. Information sources are largely previous experience and observation. Information about the sowing characteristics of varieties is obtained from: NIAB; adviser; and ADAS.

There is a need for more information on seed availability and varieties; the latter provide the farmer with recommended sowing dates.

**Variety Choice**
The key factors involved in the choice of varieties are as follows:
- all crop characteristics e.g. standing power, resistance
- field characteristics
- performance in trials, especially local ones
- market/buyer
- profitability
- planting date

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The most commonly reported external sources of information about crop varieties are NIAB and other trial reports, meetings and shows, their own field trials, local growing groups, seed company literature and the farming press. Farmers may also use information on varieties from friends and neighbours.

This is an information intensive area and one in which both farmers and advisers may suffer from an overload at certain points in the year. The areas which the project may be able provide support for are:
1) provision of timely trials information
2) ability to select out aspects of the information relevant to the user
3) local results.
These facilities would be of use to both groups but particularly to advisers.

Diagnosis of pests and diseases
The diagnosis of pests and diseases may be a mixed activity but it is largely the domain of the adviser. Farmers may spot a problem in their weekly walks around the farm but many then call the adviser and leave them to make the diagnosis and assess the extent of the problem. In most cases the adviser is retained to make periodic checks on the fields for signs of trouble.

Identification relies primarily on the experience of the observer with reference to key texts; to colleagues; or to specialists from research institutes if something unusual is found.

Assessment of risk requires the adviser to weigh up a number of factors:
- crop growth stage
- weather
- knowledge of the value of the crop (gross margins)
- the usual impact of the pest or disease (pest life cycle)
- variety
Information for these results largely from experience and knowledge of the farm. External sources of information may be obtained from colleagues; from specialists; scientific papers; trials data; reports from research establishments; and the farming press.

Most advisers practice a planned approach to the control of diseases. The control of pests appears to based on observation. To this end field walking is carried out
regularly, its frequency ranging from once every three days to once every three weeks. The frequency changes based on the weather, the time of year and knowledge of potential risks gained from: experience; local information; and warnings from colleagues, farming press; newsletters and forecasts. Farmers also walk the fields on a regular basis sometimes with the adviser. If they find problems between visits by the adviser they generally contact them for advice.

While this is a specialist area it is not information intensive and relies to a large extent on the practitioners experience. However there are a number of areas where the project might make useful contributions to the work of the adviser.

1) Pest and disease models to allow the adviser to judge the potential seriousness of a problem given the environmental conditions.
2) Early warnings of occasional pests.
3) A facility to identify and sort client field information. This would enable them to plan a walking regime in response to warnings to cover their area in the most effective way.
4) A facility to aid the collation of information on new research into pests and diseases. Many provide an information service for their clients which involves summarising data of particular interest to them. This is still largely a paper based operation and as such is extremely time consuming.

Weed problems
The nature and extent of weed problems are usually determined by observation in the previous year. Sources of information for where to spray are often hand drawn field maps showing the location and density of each weed population.

This is not an information intensive area and is often covered by the farmer alone. Recording the location of weeds accurately year by year was seen as the main problem in this area.

What active ingredient and rate of application
This is generally an advisers decision and the factors they use in making it are:
- extent of the problem
- cost effectiveness of chemical
- value of crop
- availability of chemical
- weather
- effect on the crop
- growth stage
- effect on the environment

This is one of the most information intensive areas and external knowledge is obtained from a variety of sources: notes produced by the chemical manufacturers; chemical company data sheets; trade meetings; and trial data from any available source. Chemical representatives have greater access to manufacturers information.

If farmers are involved in the choice and rate of application of active ingredients they base their decision on the ease of application and the advice of advisers in addition to the factors mentioned above.

There are several areas where improvements in this decision area could be made:

1) Access to manufacturers information.
2) Access to accurate cost and availability data. Many farmers and advisers said they would like this but doubted that it would be possible to ensure that the information was correct.
3) Access to information on the action of chemicals for farmers. Farmers often said they would like to be able to understand the reasoning behind the choice of chemicals made for them by their advisers.
4) Access to compiled or sorted research information for advisers and more technically minded farmers.

Choice of chemical vendor

The choice of vendor depends on the arrangement the farmer has made for the provision of chemicals. They may be part of one of several schemes:

- **Use of a chemical company's free agronomy service.**
  In this case they will be supplied with chemicals as part of the deal. The chemical company chooses the manufacturer they deal with who offers the best 'mark-up' on the product.

- **Use of an independent representative.**
  The representative may also undertake to source the chemical for the client. As they charge directly for their services they will choose the supplier offering the most cost effective deal for their client.

- **Membership in a buying group**
  A group of farmers will join together to get the best price for their chemical needs.

- **Grain buyer.** In some cases the grain buyer provides both advice and chemical. Farmers may also choose to buy directly from suppliers based on the prices they are offered.
As most of the chemicals are sold in mixes the main problem for all groups apart from the chemical companies is attempting to identify who is offering the best price for the target ingredient and which mix is the most cost effective. Support for this decision would be:

1) Provision of accurate data on mixes and prices offered by chemical companies.
2) Facility to cross reference data on price and the components of a mix from different companies.

When to spray
This decision was generally rated as mixed in the survey. Advisers were responsible for providing the optimum date and farmers for scheduling the actual spray date. In addition to the advice from the agronomist the farmer will use the following factors to decide on the date:

- weather (land condition, wind, rain)
- availability of personnel
- urgency of problem
- value of crop
- label specifications

With the exceptions of manufacturers labels and weather forecasts these factors are all based on 'internal' information i.e. information available in the farm.

The adviser makes the decision on the best spray date based on:

- a yearly plan
- growth stage
- plant resistance
- knowledge of the farms constraints
- chemical recommendations
- weather
- research results

Where the adviser is also responsible for the spraying of chemicals the need to schedule a range of clients also has to be taken into account. The decision is largely based on previous experience and knowledge of the clients needs but where external information is required it is obtained from: chemical data sheets; the 'green book' and published research findings.

This is a decision which is mostly based on a persons experience. However support could be provided in the form of:

1) Access to chemical company recommendations.
2) Access to (compiled) research information.
3) Access to accurate, local weather forecasts.
4) Sorting and scheduling facilities on client databases for contract sprayers.

**Nutrition**

The decision about field nutrition is largely taken by the farmer based on:
- knowledge of the fields history
- results of soil tests
- condition of the crop
- availability of farmyard manure

Field records and soil tests are the most important sources of information. Nitrogen levels are usually determined by the farmer; soil tests for P & K are usually conducted by the fertiliser companies and advisers. These people will recommend a level of nutritional supplement based on the results of the tests. Additional support is obtained by using Fertiplan and Optimix (commercial computer programs).

Satellite information on field health was used by a number of farms for the first time last year.

The areas where support could be provided are:
1) Provision of nutritional (and yield) information specific to areas of the field. The driving force behind this appears to be set-aside and the possibility of taking poor land out of production.
2) The ability to match the spray rate for nutrients to the variable field information obtained by (1).

**When to harvest**

This decision is most commonly the farmers' advisers use this time to take their annual holidays. Two main factors determine the date of harvest:
- the readiness of the crop
- whether its feed or milling wheat
- the weather.
- state of the market
- the availability of people and machinery (on larger farms)

The readiness of the crop is usually indicated by moisture meter or by 'bite'. While the rule of thumb appears to be 'cut as soon as possible', there is a trade off between the need to be finished before the weather breaks and the desire to cut the costs of drying indoors. Increasing pressure for drier grain from the buyers is making this decision more crucial to the farmers profit margins. Experience and farm knowledge
are major sources of information for this decision although weather forecasts also provide an important input.

This decision area requires the least amount of support. The main problem in this area is the accuracy of local weather data: it would appear that any improvements would be welcomed.

**Scheduling work**

Scheduling of farm work is a task which has two main stages. The first is long term planning of crops and machinery purchases and the second is the day to day planning required to implement those decisions. It seems to be impossible to plan on a weekly or monthly basis in farming as the unpredictable nature of weather and biological systems demands an instant response. Long term plans are often altered by these day to day realities. While this is a decision area predominantly based on farmer experience and the weather, advisers may be asked to provide information on prioritising tasks.

As with many other decision areas the provision of accurate and local weather data would be useful.

**Safety issues**

Decisions about safety tended to be seen as fairly low input and low priority by many farmers particularly on the smaller farms where the spraying is done by the farmers themselves. It is less true of the larger farms and those employing farm managers. The information sources they use are advisers recommendations, training courses, chemical labels, manufacturers instructions and the COSHH regulations.

Advisers are generally more concerned about safety issues although they are not directly responsible for carrying them out. They usually provide advice with chemicals and will point out deficiencies where they are observed. Chemical companies, as part of their own self regulatory body, make safety advice available to farmers in palatable forms e.g. posters.

Support in this area could be provided for advisers in the form of:
1) Databases of chemical and other safety information
2) Facilities to sort/extract relevant parts of this information for presentation to clients.
Financial issues
Finance is part of all the above decisions. The obvious aim of all parties being to make a profit and sustain their livelihoods. The factors involved vary from situation to situation but many farmers carry out gross margin analysis when making financial decisions. Other information sources for farmers include: data on prices from suppliers; data on other farms performance from Nix and growers groups; the farming press; advisers and accountants. Advisers use much the same information to make their decisions.

Support services for this area include:
1) Gross margins analysis. Many farmers and advisers already have this facility.
2) Access to commercial data on prices especially for chemicals.
3) Support for the integration of data relating to financial matters.

3.2.5 Farm records
All farmers interviewed to date have kept farm records of some description. The information they contain however varies considerably as does the format they use. Most still use a paper based system, often an A4 hard backed book, one for each year. In many cases detailed information is kept by the farms adviser and this is more likely to be computer based.

The types of data recorded are as follows:

<table>
<thead>
<tr>
<th>Rotations</th>
<th>Estimated yield, actual yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suppliers</td>
<td>Field maps showing weeds, crops, varieties</td>
</tr>
<tr>
<td>Date of purchase</td>
<td>Stock records</td>
</tr>
<tr>
<td>Dates of drilling, harvesting and spraying</td>
<td>Weed types and locations</td>
</tr>
<tr>
<td>Cost of seed, fertiliser, chemical</td>
<td>Pests and diseases (not commonly recorded).</td>
</tr>
<tr>
<td>Rate of seed; fertiliser, chemical used</td>
<td>Spray records: location, personnel, weather conditions</td>
</tr>
<tr>
<td>Accounts, VAT</td>
<td>Gross margins</td>
</tr>
<tr>
<td>Acreage of field</td>
<td>Weather (min/max, windspeed, wind direction)</td>
</tr>
</tbody>
</table>

3.2.6 Observational data
Field walking by the adviser is the primary source of observational data, this is supplemented in most cases by walking by the farmer or farm manager. The frequency of walking depends on the time of year and the perceived level of risk. From once every 3 weeks in the slow season to once every 3 days if there are forecasts of disease.
Advisers would like to be able to access information whilst in the field and to make notes for inclusion into reports for the client. Farmer would also appreciate a handheld tool for note taking or for sketching out weed locations etc.

3.2.7 Local information
A general impression gained from the interviews was that there is a lack of local information. Knowledge about the experiences of farms in the same geographical area and of local weather and local trial data was seen by many as essential.

3.2.8 Weather data
The most common sources of weather data are television (Sunday pm particularly), local radio and the met office fax and phone forecasts. A number of farms record their own temperature and rainfall levels.

The lack of accurate and timely local weather data was cited by many as a problem area.

3.2.9 Decision making location
The current survey did not ask respondents to identify the location of their decision making. The previous survey suggested that, for the farmer, planning decisions such as what crop to plant, what variety to use and what chemical vendor and mix to use take place largely in the office or at home. This is also true for financial decisions and for decisions relating to the current weather conditions such as 'can I spray today?'. Field based decisions are generally those which relate to the identification of weeds, pests and diseases and their treatment. The adviser generally makes the decision to spray whilst in the field. Here they also decide on the type of chemical required and the dosage needed, although background reading will have taken place in the office/home on a regular basis.

3.2.10 The time taken to make decisions
The longest decisions to make concern what to plant, what variety to choose, and decisions relating to finance. Where the adviser or farmer has control over the chemical vendor and mix this is also a lengthy procedure. These are all information intensive activities.

Advisers activities which seem to take little time are those of diagnosis; choice of active ingredient and when to spray and here the decision is based on information already contained in experience. Advisers spend time every week maintaining their
knowledge on current research and best practice in all areas of crop management with which they come into contact. Planting time, harvest time, when to spray and farm scheduling decisions are taken swiftly by the farmer once the environmental conditions are right. Decisions relating to safety do not take long for either farmer or adviser and only depend on the availability of the appropriate recommendations.

The only areas where advisers suggested they had insufficient time to absorb new information was in the area of active ingredients and vendor/mix choice. Farmers on the whole felt they had enough time for any background reading they required.

3.2.11 Confidence in decision making
Looking at the data from the viewpoint of responsibility, advisers were very confident in their ability to remain up to date in the area of diagnosis, when to spray and choice of active ingredient. They were less confident about choice of vendor/mix and safety regulations. Farmers were confident about keeping up to date with information required for farm scheduling and when to spray, less confident about diagnosis, brand/mix or safety.

Advisers are confident about the decisions they make in relation to diagnosis, choice of active ingredient, mix and brand and when to spray. They are less confident about their decisions relating to variety choice, planting time and safety. Farmers are fairly confident about their decision on choice of crop and harvest date but less on variety, planting time, diagnosis or safety.

Both farmers and advisers felt that their own experience was essential in making all decisions.

3.2.12 Free time?
While farmers are generally busy, some times of the year are less so; particularly for arable farmers. The survey suggests that arable farmers have more time to spend on long term and strategic decisions between December and February and in the weeks prior to harvest. Arable farmers may therefore be able to spend time looking at variety and market choice. Mixed farms tend to be busy throughout the year and are more likely to leave all scientific and information based decisions on their wheat crops to an adviser.
3.3 The ideal system

3.3.1 Initial ideas
In the previous survey respondents produced many interesting ideas about the systems they felt would make their lives easier. These ideas were categorised under 5 main headings; farm data; financial tools, on-line services; databases and advice/utilities. In the interests of completeness descriptions of these ideas are reproduced from UNG 1.0.

| Farm data | The ability to store farm records was seen as important (see previous section for types of data currently recorded). These might be linked to field maps and external information sources e.g. satellite. It should enable users to record, display and print out the location and strength of weeds, pests, diseases and nutrition. |
| Finance | One of the most commonly requested functions was the ability to so 'what if...' scenarios relating to finance; to enable the user to play with possibilities and see the likely outcomes of a decision before actually taking it. The ideal system should incorporate the cost analysis system they currently use but allow it to 'talk' to and use input from other sources of information. Failing that a simple means of transferring their existing data to a new format would be required. Several people requested a computer version of the Nix handbook. |
| On-line services | Many users felt that linking directly into 'on-line' services was costly and time consuming. They are happier with the idea of services which send information to them either via the computer or a fax machine. Information they would like to access by this means are: chemical prices; market prices; local weather forecasts; chemical availability; seed availability; and disease and pest forecasts. The need to find out what was going on locally could be fulfilled by use of a 'bulletin board'. |
| Databases | These would ideally be disc or CD based and permit easy searching on key-words and facilities to copy information to other files for collating, sorting etc. Users requested databases on: trials results; journal abstracts; press reports; research information; chemical data; and safety data. |
| Advice/utilities | Tools to provide access to scientific knowledge, either in the form of guides e.g. a disease/pest diagnosis programs using photographs on CD ROM, or 'what if...' simulation tools. The reasoning behind the advice given by these facilities should be transparent, no trust will be placed in systems which simply 'give the answers'. A scheduling support tool was also mooted in the report from the first survey. This is now seen as useful only to the adviser for scheduling visits. |
| System characteristics | Based on the first survey it was suggested that the ideal system for both farmer and advisers would consist of; a powerful portable capable of storing the wide range of information required by advisers and fast enough to cope with the calculations farmers may require it to make when using their simulation tools and gross margin calculations; an in-built modem and fax/printer facility; a larger screen and full keyboard for office use; and a pen based 'notebook' for field use. To avoid problems associated with the transfer of data, these items could be plugged into the portable as external devices, leaving the portable to act as the 'hard disc'. |
3.3.2 Results from the scenarios

Some of the ideas described above were incorporated into 'scenarios', described in section 2.4, and presented to the second set of respondents to check their validity. Each scenario with a summary of the comments it generated is presented below.

Farmer scenario 1: Planning varieties for next year (location - in the house)

You switch on your PC to check the post and discover that the last of the trials information you subscribe to has arrived. Unlike the old paper versions its sent out immediately after completion of the trials and arrives in time for next years decisions.

A little later in the day you decide to make a start on picking next years varieties. As usual there is a huge amount of data to sift through so you open up the variety selection program to make life easier. The program helps you select varieties by removing any which do not match either the yield set by your existing variety or any additional criteria you set e.g. early cropping, drought resistance, fungal resistance; thereby reducing the number of specifications you have to look at.

The program can access your field records so it knows what previous crops you've grown and the yields you've recorded for them. It also contains an estimate of each of your fields performances compared to the yields given by each of the trials locations, information which you gave it when you first used the program. Eg the trials results from location x may be fairly accurate, but the superior soil type in location y means that you have to reduce the yields quoted by 15% to get a realistic estimate. Glancing at the settings you feel that the estimate you gave for Blossom Hill field was a bit low, particularly since you put that unproductive bottom corner into set-aside. You type in a new higher figure.

Initially you ask the program to compare all your field records against this years trials to see if there are any new outstanding varieties. The program shows you the performance of each variety you grew last year (plus an average of previous years performance) for each field vs the expected yields of any varieties which match or exceed the figures you produced.

Quite a few varieties appear on the screen. Given the wide choice you decide to state some additional requirements. With the size of the spray bill firmly in mind you ask the program to select those varieties with a high disease tolerance. The screen suddenly becomes less cluttered. The expected yield of some of these varieties looks quite interesting so you request a print out of a full description of each of them to take and read in a comfortable chair with a cup of tea.

This scenario produced a mixed response. While some farmers liked the idea of support for variety choice, and felt it would improve their decision making e.g. 'I might base my decision on real information rather than gut reaction.', others were less enthusiastic. These people felt that the decision was, for them, not sufficiently complex to warrant the time, and more importantly, cost, of using such a system.

Ideas that respondents felt would be useful to them were:

- A computer linked into satellite information to plot the areas of nutritional deficiency in their fields.
- A method of collecting and displaying local information on variety performance.
- On-line and local meteorological data.
- A system to support budgeting through the year.
Farmer scenario 2: Should I spray (location: farm office)

Your adviser has just finished walking your fields and comes into your office with a gloomy face. There is an outbreak of XX and your Winter wheat crop has a nasty attack of it. The adviser suggests that an emergency application of chemical Y will save a good percentage of the crop if applied quickly.

You need to decide if this is a cost effective option so you call up your field management package and select data on the 3 fields in which you have winter wheat. The screen displays each fields expected yield, the expected value of that crop, the expenditure to date and the gross margin. You call up the 'What if...' function to help you check the effect of treatment on your profits.

The 'What if' display prompts you for the chemical you wish to apply, the rate of application and for figures on the expected losses with and without treatment. When you enter the name of the chemical it automatically checks your records to see if you have any in stock. Unfortunately this is a chemical you haven't used previously and so the program asks if you would like it to enter a standard price from the chemical companies on-line price list or to enter your own value. You decide to use the on-line price for the time being, you know you can get a better price but may as well calculate for the worst case. After a few seconds the unit price for the chemical appears and the program calculates the gross margins before and after spraying based on the estimates you have given it.

Glancing at the figures you realise you definitely have to spray two of the fields, the cost of not spraying outweighing the additional cost of the chemical even at the price you've entered. The third field will still lose money even with treatment and so you remove it from the 'What if' spray calculation and observe the effect on overall profit. The figures indicate that your overall profits are greater when the third field is included in the spray program even though alone it will lose money.

You choose to open the 'spray manager' from within the 'What if' program. This program picks up the information you entered about spray rate and the quantities required and displays the contact names and numbers of your usual suppliers. You send a standard email to all the suppliers and ask them to send you a price for the quantity you need.

The treatment will have to be applied as soon as possible so you open the 'Met folder' to check the weekly weather file. The forecast suggests that you're likely to get a calm spell towards the end of the week. You type 'Friday' into the date slot in the spray manager program and the program automatically suggests the names of the operator(s) and vehicle(s) available for that day. After you've chosen one you select 'print' and the spray instruction sheet complete with the correct chemical safety instructions is printed out ready to hand to the operator.

In general the idea of a system for checking on cost benefits and chemical availability was not appreciated by farmers. They felt that such a system would cost a lot of money and might not be justifiable for the benefits it could offer.

One of the major concerns with the system described in this scenario was that many things would depend on data being updated regularly, by themselves and by the operators of services such as the met office or chemical suppliers. They personally felt that they would not have the time to keep the farm records up to date and were convinced that the failure of others to maintain updates would render it invalid.

They were, on the whole, sceptical of the ability of forecasts to be useful to their locality or up to date. They felt that the idea of using a computer for day-to-day scheduling on the farm was unworkable because of the unpredictable nature of the job: the idea that a program could predict yield loss or that someone might know the predicted yield or market value was seen as unrealistic.
Another major concern was that the use of a computer in this way would replicate the job of their adviser which they were unwilling to do. It was suggested that the system might be more useful for the adviser.

Farmers did feel that a computer system could be useful in several ways, namely:
Linked into satellite information to plot areas of nutritional deficiency in their fields.
Storing and displaying local information.

**Adviser scenario: Should I spray (location: office, car, farm)**

You switch on your machine in the office in the morning and scan through your mail. Among the data-sheets and notes from clients you see a disease warning from one of the monitoring services you subscribe to. You know its serious when you do a quick search on the disease name in the advisers news reports and find reference to outbreaks further south in the past few weeks.

Most of your clients grow the affected crop (winter wheat) so you’ll have to do some serious scheduling to get round them all as soon as possible. You call up your scheduling package and ask it to search through the client base for all clients growing winter wheat; and as you expect its a large list. You select the ‘priorities’ option and ask that fields further south, those below a certain elevation or with a previous history of the disease to be brought to the top of the list. When the list is sorted you select the first half dozen plus several other fields you know from experience are good indicators of this disease before hitting the ‘schedule’ key. The screen displays a map showing approximate locations of the chosen fields, with a suggested route between them and you hit ‘print’ to get a hard copy. Before you leave the office you send out an urgent email to all clients on the list telling them of the warning. Unplugging your PC from the external monitor and keyboard you pop it into its case and into the car, taking care to check that your pocket notebook computer is also packed.

Not long after arriving at the first field you find evidence of the disease. You use your pocket notebook computer to jot down the location and severity of the attack and the rate of chemical you feel would control it before moving on to the next field on this farm. All three fields are affected and you know its going to be hard to persuade the farmer that spraying at this stage will be cost effective. Before going to the farm office you decide to prepare some persuasive paperwork. You open up the portable in the car and download the information from your pocket computer. When the downloading is complete you access the ‘farm management’ package and call up data on the 3 fields in question. The screen displays each fields expected yield, the expected value of that crop, the expenditure to date and the gross margin.

To find out the costs with and without treatment you select the ‘What if..’ function which prompts you for the chemical you wish to apply, the rate of application and for figures on the expected losses with and without treatment. When you enter the name of the chemical it checks your database to see if you already have a price for it and enters it and the supplier name automatically. You know that you may be able to get a better price from another supplier but decide to go with the figure given for the time being.

The program has calculated the gross margins before and after spraying based on the estimates you have given it and glancing at the figures you realise the farmer definitely has to spray two of the fields, the cost of not spraying outweighing the additional cost of the chemical even at the price you’ve entered. You print out the screen display on the PC printer. The third field will still lose money even with treatment and so you remove it from the ‘What if’ spray calculation and observe the effect on overall profit. The figures indicate that the clients overall profits are greater when the third field is included in the spray program even though alone it will lose money. You print this display out as well.

After some discussion the client agrees to spray all three fields at the rates you suggest. The treatment will have to be applied as soon as possible so you open the ‘Met folder’ to check the weekly weather file which was updated automatically that morning. The forecast suggests that you’re likely to get a calm spell towards the end of the week. You open your ‘spray manager’ application and select the three fields in question. The chemical name and rate you suggested earlier have been saved with the field data and are automatically pasted into place on the screen. You select ‘print’ and the spray instruction sheet complete with the correct chemical safety instructions is printed out ready to hand to the operator.

This scenario generated a cautious but generally positive response from the advisers interviewed. The positive comments were largely for the idea of having access to
good database manipulation tools, e.g. for identifying who was growing a particular variety or checking on the effect of spray regimes over a number of years. The use of a portable with the ability to access and print out recommendations was also seen as a good idea (a couple of firms are already investing in the technology). Some advisers liked the idea of a database of chemical 'best buys', or optimum mixes: the idea of being able to do costings for the farmer on-site was also appreciated.

They felt however that the scenario was wrong in several important aspects. Firstly farmers rarely need persuasion to spray fields, 95% of the time they do what is advised. Secondly advisers not need assistance in identifying key fields, this is part of their knowledge. Scheduling generally might be useful, as might a coded map for larger areas, but on the whole they know which fields should be seen first. They also felt that the situation as described was very rare and that they would be more likely to spot a disease than to hear about it from a computer. The possibility of being able to predict effects on a crops value with and without treatment was seen as fanciful.

They did not like the idea of emailing clients before a visit as this action would result in constant phone calls from anxious clients. They also did not like the idea of a computer telling them to 'do this now' - they already know. Finally they did not consider that any program which used weather averages would be useful.
4.0 SUMMARY

The purpose of this survey was to extend and validate the findings from the first set of interviews carried out in September 1994. In particular to increase the number of larger farms represented in the sample. This has been accomplished and the results summarised here are based on a sample of 32 farmers, with farm sizes ranging from 14 to 1150 acres of cereal; and 12 advisers with cereal coverage of between 2,500 and 14,000 acres.

The main impression created by both surveys is one of consistency; the same requirements appearing again and again. The initial expectation was of a range of disparate groups with differing needs but the reality appears to be a continuum of requirements, from low tech farmer to high tech adviser, with an overlap of requirements in the middle ground.

There was little evidence of technophobia in either survey: while not all farmers use computers the main reasons for non-use are the size of the business and a perception that the software they need does not exist. Older farmers and smaller farms are least likely to use computers and larger and mixed farms are more likely to use them.

4.1 Summary of the decision process

On average the decisions made by the two groups can be distinguished on the basis of their type, strategic or tactical; and their requirement for external information. Those decisions made largely by farmers are strategic and require little external information e.g. planting, spraying and harvesting. Those made by the adviser are tactical and information intensive e.g. the need for insecticides, fungicides and herbicides and the best rates of application. As the gathering and collating of information is time consuming it follows that most farmers find it cost effective to leave these decisions in the hands of an agronomist. The exceptions tend to originate from the larger arable farms.

The role of the adviser is seen as crucial. Most farmers, depend heavily on their consultants for technical advice, particularly in the area of chemical selection. Advisers are employed to spread the burden of stressful decisions, in particular in areas in which the farmer is less confident; and the value of this 'reassurance' role should not be underestimated. Trust in the value of the advice is critical to maintain reassurance and farmers believe that, on the whole, advisers provide the best advice possible for the circumstances. When crops do perform badly other variables, such
as the weather, are blamed rather than the judgement of the adviser. Another reason for this lack of criticism from a generally astute population may be the knowledge that their actions may be part of the cause: farmers do not always follow their adviser's instructions to the letter. Situations where farms have changed hands or where two farms merge but maintain two advisers provide exceptions to this rule.

The vast majority of information used in decisions in wheat production are 'farm based' e.g. soil conditions, current weather, field history, machine availability. Most farmers store field related and market data in some form or another and there are great benefits for the larger farms in moving to a computer based system e.g. for checking a field's performance. However much of the 'farm based' data is highly volatile e.g. machine or personnel availability, and the farmer is not willing to spend time recording it. The common view is also that day to day scheduling is so changeable that scheduling tools would be an encumbrance rather than a help.

Given the strategic nature of their tasks and the 'onhand' availability of much of the information they require to carry them out, it is not surprising that farmers are less than enthusiastic about many of the proposed decision support ideas. It would appear that the most useful facilities for them will be those that provide support for financial decisions.

It is the advisers who stand to benefit most from the types of decision support tool the project is examining. A sizeable part of their job concerns collating and keeping up to date with information from external sources. As farmers for the most part rely on them to make decisions concerning the use of pesticides, it is perhaps here that the most important savings could be made. If the 'continuum' model of decision making is valid then the more technically minded and larger farms will also gain from the same facilities.

4.2 Summary of user requirements

Based on the results of the two surveys it is suggested that the functions and features, outlined below, comprise the key user requirements for decision support systems in winter wheat crop production.

- Access to information on: markets; varieties; seed availability; trials results; chemical manufacturers specification data; chemical mixes; chemical costs; availability of chemicals; and research data.
- Access to local information on: weather; trials; and variety yields.
- Increased accuracy of local weather information.
User requirements for decision support systems
UNG/2.0

- Scientific data in the form of: compiled research results and pest and disease simulation models.
- Tools to support the integration and compilation of data.
- Tools to support sorting, cross referencing and analysing of database records.
- Financial tools to support 'What ifs' and gross margins analysis.
- Facilities to support the recording of farm data including locations of weeds, nutrient deficiencies etc. and to link into satellite information.
- The ability to share data between a range of applications.
- Ease of use.

The 'ideal system' might therefore provide the user with:

A facility for storing farm records e.g. sowing, harvesting dates, crop rotation, varieties and notes. This will include links to farm maps and to satellite information to allow the user to record, display and print out the location and strength of weeds, and nutritional deficiencies.

The ability to so 'what if...' scenarios relating to finance. For example to calculate the costs and impact of fertiliser use. This facility should allow the user to play with possibilities and see the likely outcomes of a decision before actually taking it. This facility should also link into the cost analysis system they currently use and also 'talk' to and use input from other sources of information, e.g. the Nix handbook in electronic form.

The ability to receive information automatically from external sources. The information could be requested directly but more usually would be delivered on a weekly/monthly basis to the users machine during off-peak hours.

A local electronic 'bulletin board' to allow farmers and advisers in the region to post information about yields or other locally important matters.

Access to disc or CD based databases e.g. trials results, journal abstracts, press reports, other research information, chemical data and prices and safety data. Ideally it should permit easy searching using key-words and offer facilities to copy information to other files for collating, sorting etc.

Note: There may be two problems here relating to the information providers. Firstly many providers have complex copyright regulations and may not be willing to allow their information to be incorporated into other documents. Secondly the chemical companies are likely to be unwilling to allow free access to commercially sensitive information such as their price lists and the contents of their mixes.

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Provision for advice and utility 'modules' to be 'plugged in'; providing access to scientific knowledge, either in the form of guides e.g. a disease/pest diagnosis programs using photographs on CD ROM, or 'what if...' simulation tools. These tools might allow the user to see the effects of, for example, of pest attack on yield and suggest the best time for spray application. They might allow the user to test the effects of different spray timings or different levels of fertiliser application.

Key user requirements for the hardware seem to be:
- Portability: access to computer facilities in the car, field, home and office.
- Inclusion of printing facilities for advisers.
- Communication facilities.

The ideal machine is likely to be a powerful portable P.C. capable of storing the wide range of information required by advisers and fast enough to cope with the calculations farmers may require when using their simulation tools and gross margin calculations. It would have an in-built modem and fax/printer facility and could be used as a portable in the car and at home.

It would be capable of plugging in to a larger screen and full keyboard for office use leaving the portable to act as the 'hard disc' and thereby avoiding problems associated with the transfer of data. A pen based notebook would be provided for field use, allowing rough sketching and form filling activities to take place. These files could then be downloaded into the portable for incorporation into farm records, customer reports etc.

4.3 The next phase
The next stage of the user requirements process is to present the results of these two stages to a sample of those users seen to be central to the pesticide decision making process; the advisers and farm managers. A series of three workshops is planned for March 1995; the first for the User Needs Group and the second two for the 'Farm managers Group' and ADAS advisers respectively. During the workshops the participants will be informed about purpose of the research and asked to give their views on the results of the two surveys. To assist them in the visualisation of the future decision support environment they will be given an impression of its potential 'look and feel' by use of a piece of demonstration software.

These workshops have several objectives to obtain feedback on the accuracy of the requirements identified by the surveys; to obtain feedback on the solutions we have
proposed and where possible gain further detail; and to ensure 'ownership' of the results by a sample of future users of the system.

5.0 CONCLUSION

There are likely to be two main thrusts of the LINK project work; the first concerning the development of a framework to facilitate communication between software packages; the second concerning the facilities to be provided for the user.

The conclusion of this report is that the first of the above concerns is vital. The ability to integrate information from a variety of sources will be required if users are to move from paper based to computer based methods. The integration of materials also forms a large part of the work of the advisers, and it is these people who are likely to be the primary users of the proposed system.

The functions which are conceivably of the greatest value to advisers are: the ability to access local and remote databases; the ability to manipulate database contents; and the ability to incorporate their findings into other documents. Access to compiled scientific data in the form of research summaries and simulation programs is also seen as very important. It should be noted that the value of much of this information will depend on the ability of the information providers to keep it up-to-date.

Facilities which may be of equal use to advisers and farm managers are those which support the recording of farm data and those which support financial calculations and financial 'what if's.

These requirements have been refined from interviews with 44 potential users in two separate surveys and the findings have remained reasonably consistent throughout. However the validity of these requirements and that of our proposed solutions will be tested again in the user workshops in March 1995.
APPENDIX A

QUESTIONNAIRE USED IN THE SURVEY
APPENDIX B

SCENARIOS
APPENDIX E: DESSAC Postal Survey


By Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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Postal Survey of User Requirements

DRAFT

Document UNG/3.0

Decision processes for winter wheat. User requirements for future decision support systems.

August 1995

User Needs Working Group

Caroline Parker.
HUSAT Research Institute
EXECUTIVE SUMMARY

During 1993 and early 1994 discussions between MAFF, HGCA, crop agronomists and researchers, as well as representatives from the agrochemical industry, developed a series of ideas on arable crop decision support systems (DSS). These culminated in a project proposal, supported by MAFF and the HGCA Research and Development committee, which would be part of the MAFF Link programme on technologies for sustainable agriculture.

In view of the ambitious nature of this project and the need to establish clear user requirement baselines, MAFF has provided funds to allow some preliminary work to take place during the current financial year ending in April 1995. This support has enabled the first phase of the determination of the user requirements to be undertaken.

A preliminary investigation was undertaken into the needs of future decision support tool users in the cereal industry. In particular it aimed to determine the potential range of users, the different requirements they may have, the information sources they currently employ in decision making, the value of these sources and their understanding of what would help them to become more efficient.

Section 2.0 of this report describes the methods used to gather this information and Section 3.0 summarises the results obtained. A discussion of the results is provided in Section 4.0.

The conclusion of the survey was that, in view of the consistency of findings reported, the group shift focus away from high level requirements analysis to more detailed developments. It was also recommended that initial development of system modules should focus on the 'decision support areas 'choice of varieties' and 'choice of chemicals'.

Finally the view of the future decision support system which emerged from this survey is one of a portable, user friendly device which links into the communications network and other recording devices and supports the user by providing access to information (databases), confirmation of decisions, advice and 'what if..' scenarios.
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Appendix A: Questionnaire used in the survey
Appendix B: Detailed data from farmers responses to the survey
Appendix C: Detailed data from consultants responses to the survey
1.0 INTRODUCTION

This document describes the results of the third stage of the user requirements analysis for the DESSAC project.

In September and October of 1994 initial interviews with two discrete groups of potential users took place. These interviews were focused on the requirements for the DESSAC system as a whole. They aimed to identify the information needs of users, the sources of that information, and the interactions between the individual decisions that make up the range of actions in arable crop production on the individual farms. The results were reported to the User Group on the 26th October 1994 and presented in UNG 1.0.

The findings from the first stage were considered to be interesting. However the size of the user sample was considered by the Group to be inadequate and the acreage of the farms in the sample too small to be truly representative.

A further set of interviews were carried out in November and December of the same year and the results were reported to the User Group in January 1995, the Coordination group in March and, following an additional meeting with a group of large scale farmers in April, the Technical Group. The results of the combined studies were also presented in UNG 2.0 and summarised at a meeting of the full project group in a workshop at Hitchin in early May.

Several concerns were raised during those presentations which have led to the current research. These were:

- Limited sample size
  Despite the increase in number and farm size represented by the second set of interviews there was a feeling among the workshop representatives that the results might not be representative of the farming population. In particular not representative of the larger scale farmers who, it is believed, would be the initial and main users of the DESSAC system in the future.

- Need for specific fungicide requirements
  The workshop also felt that there was an urgent need to identify the specific requirements for the fungicide module of DESSAC. In particular the information required to make good fungicide decisions. The original surveys had focused on the broader aim of DESSAC as decision support for arable crops.

- Need for an understanding of the broader range of farm decisions
  While there were calls for a narrowing of the focus of the user requirements research there were also those who felt that the focus should be broadened. It was believed that, the start of the project would be the best time to identify the full range of farm decisions to ensure that the DESSAC system would sit comfortably among them and hopefully at some later date incorporate them. Failure to do so might result in a system which was not used because it didn't fit in with these, potentially more important, decision areas.
The purpose of this third survey is, therefore, to validate and expand the user requirements identified in the first and second set of interviews with a larger sample than previously employed. A postal questionnaire was identified as the mean by which this could be most effectively carried out in the timescales. A series of questions were devised by the User Needs Working Group to meet the previously mentioned three aims: first to validate the key decision areas in arable farming and the facilities which might support this process; second to identify the information users require to make good decisions about the use of fungicides on winter wheat; and third to identify the main farm decisions which potential users of DESSAC have to resolve.

2.0 METHOD

2.1 Design
The purpose of this survey was to validate and expand the user requirements identified in the first and second set of interviews with a larger sample than previously employed.

2.2 Users
The survey was targeted at members of the Morely Research Centre mailing list as this group contained a large number of arable farms of a variety of sizes. In particular it included many of the larger arable farms under-represented in the earlier surveys.

2.3 Sample size
Seven hundred and fifty questionnaires were distributed to members of the Morely Research Centre mailing list.

2.4 Materials
A questionnaire was developed and agreed by the User Needs Working Group the full text of which can be found in Appendix A. The questions were designed to elicit the following information:

- Profile of the respondent.
  - The county they live/farm in.
    To identify the geographical spread of the respondents.
  - Farmers - The farm size and percentage of arable and wheat crop.
  - Consultants - The area of land they advise on, the number of farms and percentage of arable land within it.
    To identify the type of farms and their potential interest in the DESSAC system.

- The respondents computer use.
  - Whether they own a computer and of what type.
    To identify the potential market for DESSAC and the platforms it has to support.
  - Who uses the computer and how often.
To identify the current users of computers and determine the extent of computer use by farmers and consultants themselves.

- At what times the computer is used. 
- To identify the pattern of use.
- What the computer is used for. 
- To identify the current uses of computers and determine the extent to which they are a central part of farm management.
- What crop management software respondents are currently using if any. To determine the use of crop management software in general and the types of systems they are accustomed to using.

The decision areas respondents consider important when growing winter wheat. The questionnaire provided respondents with a list of those areas identified by previous research and asked them to select the areas they felt offered them the greatest potential for savings of time or money. Space was left for additional decision areas should the respondent feel important areas had been omitted. The aim of this question was to validate the existing list of decision areas and to determine the most critical areas for future decision support systems.

The information farmers and consultants consider a) important and b) essential when making decisions about fungicide application. A list of information which might be used when making decisions about fungicide use was provided and space left for additional information the respondents might feel was missing. The questions asked them first to identify any information they believed to be important when making their decisions and secondly to identify from those areas any they thought to be essential i.e. information which would prevent a good decision being made if missing. The aim of this question was to identify the specific requirements for the fungicide decision support module being developed as part of the DESSAC project.

The most important decisions farmers and consultants have to make with regard to the farm as a whole i.e. those most critical to its success. Ten spaces were provided for respondents to identify the main 'whole farm' decisions. This questions was included to provide the project with an overview of decision making on the farm. To identify the full range of farm decisions to ensure that the DESSAC system would sit comfortably among them.

The source and type of weather data currently used by farmers and consultants. Respondents were asked which of the following data sources they used: local weather information, on farm sources, meteorological office, and radio or TV. More than one choice was permitted. They were also asked what, if any, weather data they recorded on the farm from a choice of: windspeed, wind direction, rainfall, min/max temperature, relative humidity. and 'other'. The last category was provided to allow the respondent to enter their own type of weather data if it was not contained in the previous list. These questions were asked to provide DESSAC with information on the type of local weather data available for use by decision support modules.
The use of crop consultants by farmers and their source of chemical supply. Farmers were asked if they used a crop consultant and if so to which of the following categories did they belong: independent, agrochemical company distributor or another unlisted affiliation. They were then asked to identify the means by which they purchased chemicals from a list of: crop consultant or distributor representative, independent, buying group or 'other'.

The aim of these questions was partly to validate the previous research findings which suggested that most farmers use a consultant of one type or another, mostly agrochemical distributor. It was also aimed at identifying the potential requirements for chemical information i.e. the existing information flows which could be supported or additional sources provided.

Decision support facilities which farmers and consultants might find useful

This question asked the respondents to identify from a list of 32 facilities those they felt they would find useful. They were then asked to judge the extent to which those facilities would provide them with savings of time or money. The question was designed to identify key facilities that DESSAC should aim to support or incorporate.

2.5 Procedure

The questionnaires were distributed with the July mailing from the Morley Research Centre together with a prepaid addressed envelope. Seven hundred and fifty questionnaires were distributed. Replies were collected by Morley and dispatched to HUSAT for analysis. A 'cut off' date was set at July 20th after which late arriving questionnaires would not be included in the analysis.
3.0 RESULTS
Of the 750 questionnaires distributed 146 were returned by the cut off date. This equates to a 19.47% return rate. Twenty per cent is considered average for a postal survey.

3.1 Profile of respondents
Of the 146 respondents 139 were farmers and 7 consultants.

Farmers
Given the source of the mailing list, it is not surprising that most of the farmers manage land in either Norfolk and Suffolk (61% and 25% respectively) and some in both (2%). Other counties also represented in the survey were: Essex (4%), Cambridgeshire, Devon, Lincolnshire, Buckinghamshire, Gloucestershire, Hertfordshire, Northamptonshire and Kent (all 1% of the sample).

Table 1: Showing the size in hectares of the farmers who responded to the questionnaire

<table>
<thead>
<tr>
<th>Hectares</th>
<th>Farm size</th>
<th>Arable area</th>
<th>Wheat area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count % of 137</td>
<td>Count % of 137</td>
<td>Count % of 133</td>
</tr>
<tr>
<td>0-100</td>
<td>13 9</td>
<td>15 11</td>
<td>60 45</td>
</tr>
<tr>
<td>101-200</td>
<td>20 15</td>
<td>29 21</td>
<td>45 34</td>
</tr>
<tr>
<td>201-400</td>
<td>53 39</td>
<td>54 40</td>
<td>28 14</td>
</tr>
<tr>
<td>401-600</td>
<td>22 16</td>
<td>17 12</td>
<td>8  6</td>
</tr>
<tr>
<td>601-800</td>
<td>7 5</td>
<td>5 4</td>
<td>2  1</td>
</tr>
<tr>
<td>801-1000</td>
<td>6 4</td>
<td>6 4</td>
<td>0  0</td>
</tr>
<tr>
<td>1001-1200</td>
<td>4 3</td>
<td>5 4</td>
<td>0  0</td>
</tr>
<tr>
<td>1201-1400</td>
<td>5 4</td>
<td>4 3</td>
<td>0  0</td>
</tr>
<tr>
<td>1401-1600</td>
<td>4 3</td>
<td>2 1</td>
<td>0  0</td>
</tr>
<tr>
<td>1601-1800</td>
<td>3 2</td>
<td>0 0</td>
<td>0  0</td>
</tr>
<tr>
<td>Count</td>
<td>137</td>
<td>137</td>
<td>133</td>
</tr>
<tr>
<td>Mean</td>
<td>439.6</td>
<td>360.3</td>
<td>142.64</td>
</tr>
<tr>
<td>Mode</td>
<td>300</td>
<td>200</td>
<td>80</td>
</tr>
<tr>
<td>Std</td>
<td>390.5</td>
<td>321.64</td>
<td>129.0</td>
</tr>
</tbody>
</table>

A wide range of farm sizes were represented in the survey from 35 to 1722 hectares. Most farms were in the 100-600 ha range (70%) with a mean of 439.6 ha, much of this land is arable based (mean 360.3 ha, 84% of the total land area). The area devoted to wheat production is 142.64 ha on average, which represents 32% of the total land area.

In addition to arable land, 61 farmers (44% of the total) stated that they kept livestock.

Consultants
Of the 7 consultants who responded to the questionnaire 2 were based in Norfolk and 4 in Suffolk, 1 person did not answer the question.

The area of land their clients farm ranges from 3000 ha to 4740 ha with a mean of 3915 ha, all of which is arable. The number of farms this represents ranges from 7 to 30 with a mean of 21.6.
3.2 Computer Use

75% of the farmers and all of the consultants have at least one computer. Of the 35 farmers who do not currently own a computer, 8 said they would be getting one in the near future and 5 were not sure. The reasons given for not planning to obtain a computer fell into 4 main categories, 'cost benefits', 'antagonists', 'retirement' and 'outside control'. The largest was the 'cost benefit' category (11 farmers) where people were not convinced that their farm needed or could justify the expenditure; the 'antagonists' don't like or are worried by computer technology (5 farmers), the 'retirement' group consider themselves too old to learn the technology (4 farmers) and the 'outside control' group (2 farmers) describe situations where control of those aspects of farming which might make use of computers are carried out by external bodies.

Types of computer
The consultants all own an IBM type machine as do 90% of the computer owning farmers.

Most of the non-IBM type machines are owned by people who also have IBMs, however, 3 people possess word processors alone, 1 uses only a PS1 and another exclusively employs a Mesh system.

Types of computer in use

Figure 1: Showing proportion of computer types in use on farms
The most common IBM type machine farmers own is the 386/486 which is capable of running the Windows operating system, 82.5% of all IBM type machines were in this category. Of the remaining IBM types, 7% were 586's and only 10.5% were of the older 286 variety which is not capable of running Windows.

For the consultants 6 out of 7 use a 386/486 machine, the other did not specify. In addition 2 make use of portable machines and another employs a word processor.

Who uses the machines?
Of the farmers who have computers 87 said they used the computer themselves (83.65% of those who have them).

Table 2: Showing proportion of people who use the computer in addition to the farmer

<table>
<thead>
<tr>
<th>Other person</th>
<th>No.</th>
<th>% of 47</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secretary</td>
<td>28</td>
<td>59.57</td>
</tr>
<tr>
<td>Wife</td>
<td>11</td>
<td>23.40</td>
</tr>
<tr>
<td>Children</td>
<td>9</td>
<td>19.15</td>
</tr>
<tr>
<td>Managers</td>
<td>5</td>
<td>10.64</td>
</tr>
<tr>
<td>Admin Staff</td>
<td>3</td>
<td>6.38</td>
</tr>
<tr>
<td>Partners</td>
<td>3</td>
<td>6.38</td>
</tr>
<tr>
<td>Farm Foreman</td>
<td>2</td>
<td>4.26</td>
</tr>
<tr>
<td>Total other people</td>
<td>61</td>
<td></td>
</tr>
</tbody>
</table>

Of the machines used by these respondents 47 (54%) are also used by others. The most common 'other users' in these cases are secretaries, wives, children and managers.

This picture is fairly similar to that presented by those who do not use the computer themselves. Most of the actual users are secretaries, administration staff and wives (59%, 8%, 33% respectively, of those who don't personally use the system).

All of the consultants said they personally used the computers. In two cases a wife and a secretary also used the system.
Frequency of use

Table 3: Showing frequency of computer use for farmers

<table>
<thead>
<tr>
<th>When Uses?</th>
<th>No.</th>
<th>% of 99</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>35</td>
<td>35.35</td>
</tr>
<tr>
<td>Every few days</td>
<td>51</td>
<td>51.52</td>
</tr>
<tr>
<td>Weekly</td>
<td>9</td>
<td>9.1</td>
</tr>
<tr>
<td>Less than once a week</td>
<td>4</td>
<td>4.03</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>99</td>
<td>100.0</td>
</tr>
</tbody>
</table>

(6 missing data points)

Figure 4: Showing the frequency with which farmers use computers

The data suggests that computers are used regularly on farms, around 86% of farmers use them more than once a week and 35% use them daily. The largest percentage of farmers (51.5%) use their computers every few days.

Table 4: Showing frequency of computer use for consultants

<table>
<thead>
<tr>
<th>When Uses?</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>2</td>
</tr>
<tr>
<td>Every few days</td>
<td>3</td>
</tr>
<tr>
<td>Weekly</td>
<td>1</td>
</tr>
<tr>
<td>Less than once a week</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7</td>
</tr>
</tbody>
</table>

A similar pattern is seen in the use of computers by consultants, 5 out of the 7 use them several times a week.
The data for the farmers is shown in tables 4 and 5. More than one answer was permitted to this question.

Table 3: Showing times farmers use computers

<table>
<thead>
<tr>
<th>Times</th>
<th>No.</th>
<th>% of 98</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 9am</td>
<td>21</td>
<td>21.43</td>
</tr>
<tr>
<td>Office hours</td>
<td>71</td>
<td>72.45</td>
</tr>
<tr>
<td>Evenings</td>
<td>57</td>
<td>58.16</td>
</tr>
<tr>
<td>Weekends</td>
<td>26</td>
<td>26.53</td>
</tr>
</tbody>
</table>

(6 missing data points)

Of the 98 who responded to this question most seem to use their computers during office hours (72.45%) and in the evenings (58.18%).

A further breakdown of the data shows that while many work exclusively during either office hours or evenings, there are many who work a combination of these periods.

Table 6: Showing times consultants use computers

<table>
<thead>
<tr>
<th>Times</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 9am</td>
<td>1</td>
</tr>
<tr>
<td>Office hours</td>
<td>4</td>
</tr>
<tr>
<td>Evenings</td>
<td>4</td>
</tr>
<tr>
<td>Weekends</td>
<td>4</td>
</tr>
</tbody>
</table>

Three of the consultants make use of their computers during office hours only, 3 in the evenings and weekends only and 1 at all times.

Uses of the computer

Table 7: Showing uses to which farmers put computers

<table>
<thead>
<tr>
<th>Use</th>
<th>No.</th>
<th>% of 102</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross margins</td>
<td>78</td>
<td>76.47</td>
</tr>
<tr>
<td>Farm records</td>
<td>75</td>
<td>73.53</td>
</tr>
<tr>
<td>Accounts</td>
<td>73</td>
<td>71.57</td>
</tr>
<tr>
<td>Stock records</td>
<td>50</td>
<td>49.02</td>
</tr>
<tr>
<td>Crop scheduling</td>
<td>52</td>
<td>50.98</td>
</tr>
<tr>
<td>Spray plans</td>
<td>28</td>
<td>27.45</td>
</tr>
<tr>
<td>Word processing</td>
<td>18</td>
<td>17.65</td>
</tr>
<tr>
<td>Client info</td>
<td>11</td>
<td>10.78</td>
</tr>
<tr>
<td>Staff planning</td>
<td>9</td>
<td>8.82</td>
</tr>
<tr>
<td>Communications</td>
<td>10</td>
<td>9.80</td>
</tr>
</tbody>
</table>

(2 missing data points)

The main uses of the computer for farmers appears to be gross margins analysis (76.47%), maintaining farm records (73.53%) and accounts (71.57%). Half of the sample use their machines for crop scheduling (50.98%) and stock records (49.02) and just over a quarter for spray planning (27.45%).
Respondents were asked to name the other uses to which they put their computers, other than those explicitly mentioned on the questionnaire. A wide range of uses were provided by farmers and consultants from games to weather reporting and process control. With the exception of games none of these items were mentioned more than once. The full list can be seen in Appendices B and C.

A similar picture is seen in the use of computers by consultants with 3 out of 7 using them for gross margins analysis, farm records and accounts, 2 use their systems for maintaining client records. Stock records and word processing were cited as uses by individual consultants.

Crop management software

<table>
<thead>
<tr>
<th>Software</th>
<th>No.</th>
<th>% of 59</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimix</td>
<td>46</td>
<td>77.97</td>
</tr>
<tr>
<td>Farmade</td>
<td>5</td>
<td>8.47</td>
</tr>
<tr>
<td>Sum-it</td>
<td>4</td>
<td>6.78</td>
</tr>
<tr>
<td>Farmplan</td>
<td>3</td>
<td>5.08</td>
</tr>
<tr>
<td>Own</td>
<td>2</td>
<td>3.39</td>
</tr>
<tr>
<td>Morris</td>
<td>1</td>
<td>1.69</td>
</tr>
<tr>
<td>Hylten Norris</td>
<td>1</td>
<td>1.69</td>
</tr>
<tr>
<td>Agrostat</td>
<td>1</td>
<td>1.69</td>
</tr>
</tbody>
</table>

(45 missing data points)

Of those that responded to this question approximately 78% use one of the Optimix products as their crop management system. Other products were Farmade (8.5%), Sum-it (7%), Farmplan (5%). MORRIS, Hylten Norris and Agrostat were each used by one person.

The 3 consultants who responded to this question all use Optimix CMS.

3.3 Decision Areas

Respondents were asked to identify the 5 most important decision topics when growing winter wheat. They were given a list to choose from and also allowed to write in additional topics if they felt they were important. The table below shows the responses to the decision areas provided. Note: in the event several farmers selected more than 5 decision areas.
Table 9: Importance of given decision areas for farmers

<table>
<thead>
<tr>
<th>Decision area</th>
<th>No.</th>
<th>% of 137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective spray date</td>
<td>86</td>
<td>62.77</td>
</tr>
<tr>
<td>Choice of ingredient</td>
<td>85</td>
<td>62.04</td>
</tr>
<tr>
<td>Variety</td>
<td>78</td>
<td>56.93</td>
</tr>
<tr>
<td>Fertiliser needs</td>
<td>76</td>
<td>55.47</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>76</td>
<td>55.47</td>
</tr>
<tr>
<td>Drill date</td>
<td>57</td>
<td>41.61</td>
</tr>
<tr>
<td>Practical spray date</td>
<td>30</td>
<td>21.90</td>
</tr>
<tr>
<td>Scheduling of people</td>
<td>26</td>
<td>18.98</td>
</tr>
<tr>
<td>Scheduling of tasks</td>
<td>16</td>
<td>11.68</td>
</tr>
<tr>
<td>Choice of distributor</td>
<td>12</td>
<td>8.76</td>
</tr>
<tr>
<td>Safety</td>
<td>6</td>
<td>4.38</td>
</tr>
</tbody>
</table>

(2 missing data points)

The top 5 decisions in winter wheat production would appear to be: decisions about the most effective spray date (62.77% of those who responded to the question); choice of chemical spray ingredients (62.04%); choice of variety (56.93%), decisions about fertiliser requirements (55.47%); and diagnostic decisions when faced with crop damage (55.47%).

Consultants demonstrated a similar pattern of responses. The top two decision areas were choice of ingredient and fertiliser needs (selected by 4 out of the 7 consultants). The next two, chosen by 3 consultants, were effective spray date and variety choice. There were 4 decision areas vying for fifth place, each selected by 2 consultants, these were: diagnosis, drill date, practical spray date, and the scheduling of people.

Additional decision areas identified by farmers were quite diverse although some categorisation is possible. The most frequently mentioned topics are shown in table 10 below.

Table 10: Showing additional decision areas identified by farmers

<table>
<thead>
<tr>
<th>Decision area</th>
<th>Number of suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>The condition of the soil and its treatment</td>
<td>6</td>
</tr>
<tr>
<td>General financial management of the crop e.g. marketing,</td>
<td>5</td>
</tr>
<tr>
<td>machinery purchase</td>
<td></td>
</tr>
<tr>
<td>Chemicals e.g. cost of mixes, tank compatibility</td>
<td>4</td>
</tr>
<tr>
<td>Harvest e.g. when to harvest to balance drying vs. operating costs</td>
<td>4</td>
</tr>
<tr>
<td>Cultivation e.g. seedbed preparations, timing</td>
<td>4</td>
</tr>
<tr>
<td>Timing of pest/disease development</td>
<td>3</td>
</tr>
<tr>
<td>Weather e.g. forecasts and recording</td>
<td>2</td>
</tr>
<tr>
<td>Rotations</td>
<td>2</td>
</tr>
<tr>
<td>Timing of operations</td>
<td>2</td>
</tr>
</tbody>
</table>

Decisions mentioned by single farmers were: water availability, machinery availability, environmental issues, seed rate and P.G.R.'s.
Of these only cultivation was rated as one of the top five decisions by more than 1 farmer (4), financial planning and spray mixes were mentioned by single respondents.

Only 1 consultant suggested additional decision areas, 2 of which related to fertilisers (types and costs) and the other to gross margin analysis. None of these were selected as a top decision area.

There has been some debate as to the relative importance of decision areas to farms of different sizes. In view of this the percentage of farms selecting each decision area, within 5 farm size categories, was examined in more detail, see table 11 below. Percentage figures are based on the number of respondents in each size category who answered this section of the questionnaire.

Table 11: Showing farm size and percentage of respondents who believe a decision area is important

<table>
<thead>
<tr>
<th>Farm size (ha)</th>
<th>0-200</th>
<th>201-400</th>
<th>401-600</th>
<th>601-1200</th>
<th>1201+</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. in category</td>
<td>35</td>
<td>55</td>
<td>20</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Variety</td>
<td>51.43</td>
<td>60.00</td>
<td>50.00</td>
<td>56.25</td>
<td>45.45</td>
</tr>
<tr>
<td>Drill Date</td>
<td>34.29</td>
<td>43.64</td>
<td>35.00</td>
<td>43.75</td>
<td>18.18</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>60.00</td>
<td>50.91</td>
<td>50.00</td>
<td>56.25</td>
<td>45.45</td>
</tr>
<tr>
<td>Choice Ingredient</td>
<td>62.86</td>
<td>54.55</td>
<td>55.00</td>
<td>75.00</td>
<td>27.27</td>
</tr>
<tr>
<td>Choice Distributor</td>
<td>14.29</td>
<td>7.27</td>
<td>5.00</td>
<td>6.25</td>
<td>9.09</td>
</tr>
<tr>
<td>Effective Date</td>
<td>62.86</td>
<td>61.82</td>
<td>50.00</td>
<td>62.50</td>
<td>36.36</td>
</tr>
<tr>
<td>Practical Date</td>
<td>20.00</td>
<td>21.82</td>
<td>25.00</td>
<td>31.25</td>
<td>9.09</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>57.14</td>
<td>52.73</td>
<td>55.00</td>
<td>56.25</td>
<td>36.36</td>
</tr>
<tr>
<td>Schedule People</td>
<td>11.43</td>
<td>14.55</td>
<td>25.00</td>
<td>25.00</td>
<td>9.09</td>
</tr>
<tr>
<td>Schedule Tasks</td>
<td>8.57</td>
<td>9.09</td>
<td>10.00</td>
<td>12.50</td>
<td>18.18</td>
</tr>
<tr>
<td>Safety</td>
<td>0.00</td>
<td>5.45</td>
<td>0.00</td>
<td>6.25</td>
<td>9.09</td>
</tr>
</tbody>
</table>

Figure 5: Showing importance of decisions by farm size
From figure 5 above it appears that while there is a surprising degree of similarity in the choices the decisions considered important by the size categories do differ slightly. In particular the 1200+ ha category shows a distinct difference in choices from the previous size category, most of the decision areas are considered less important with the exception of safety and the scheduling of tasks which receive a slightly higher level of support. The choice of ingredient seems to be a particularly important decision area for farms in the 601-1200 ha size category.

3.4 Information needed to make decisions about fungicide application

Respondents were asked what information they considered to be a) important and b) essential when making decisions about fungicide application. Table 12 below shows the percentage of farmers who selected each of the information categories provided. The top three items of information all related to chemical choice i.e. the range of diseases controlled by a product (73%), its effectiveness (73%) and its cost-effectiveness (69%). Disease level (67%), growth stage (62%), duration of effect (59%), weather forecast (55%) and tank mix compatibility (54%) were all chosen by over half of those who answered this question. Items which were considered important but not essential by over half those responding to the question were: current weather (65%), costs per hectare (65%), trials results (61%), recent past weather conditions (58%), environmental impact (57%), life cycle of disease (57%) tank mix compatibility's (54%), and local disease pressure (53%).

Table 12: Showing information farmers consider in fungicide application decisions.

<table>
<thead>
<tr>
<th>Information</th>
<th>Essential</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diseases controlled by product</td>
<td>73.23</td>
<td>77.17</td>
</tr>
<tr>
<td>Effectiveness of product</td>
<td>73.23</td>
<td>64.57</td>
</tr>
<tr>
<td>Cost-effectiveness of product</td>
<td>69.29</td>
<td>73.23</td>
</tr>
<tr>
<td>Disease level in crop</td>
<td>66.93</td>
<td>79.53</td>
</tr>
<tr>
<td>Growth stage of crop</td>
<td>62.20</td>
<td>75.59</td>
</tr>
<tr>
<td>Duration of effect</td>
<td>59.06</td>
<td>60.63</td>
</tr>
<tr>
<td>Weather forecast</td>
<td>55.12</td>
<td>67.72</td>
</tr>
<tr>
<td>Varietal disease resistance rating</td>
<td>53.54</td>
<td>74.80</td>
</tr>
<tr>
<td>Tank mix compatibilities</td>
<td>49.61</td>
<td>53.54</td>
</tr>
<tr>
<td>Current weather information</td>
<td>44.09</td>
<td>64.57</td>
</tr>
<tr>
<td>Cost per hectare</td>
<td>41.73</td>
<td>64.57</td>
</tr>
<tr>
<td>Previous treatments</td>
<td>41.73</td>
<td>61.42</td>
</tr>
<tr>
<td>Yield potential</td>
<td>40.94</td>
<td>64.57</td>
</tr>
<tr>
<td>Recent past weather conditions</td>
<td>38.58</td>
<td>58.27</td>
</tr>
<tr>
<td>Availability of product</td>
<td>33.86</td>
<td>39.37</td>
</tr>
<tr>
<td>Trials results</td>
<td>33.07</td>
<td>61.42</td>
</tr>
<tr>
<td>Environmental impact of product</td>
<td>33.07</td>
<td>56.69</td>
</tr>
<tr>
<td>Disease identification photos/guides</td>
<td>32.28</td>
<td>38.58</td>
</tr>
<tr>
<td>Biology, life cycle of disease</td>
<td>25.98</td>
<td>56.69</td>
</tr>
<tr>
<td>Local disease pressure</td>
<td>25.20</td>
<td>52.76</td>
</tr>
<tr>
<td>Safety information about product</td>
<td>24.41</td>
<td>39.37</td>
</tr>
<tr>
<td>Crop history</td>
<td>18.11</td>
<td>34.65</td>
</tr>
<tr>
<td>Crop position in rotation</td>
<td>12.60</td>
<td>37.01</td>
</tr>
<tr>
<td>Sprayer work rate</td>
<td>8.66</td>
<td>23.62</td>
</tr>
<tr>
<td>Interpretation of diagnostic kit results</td>
<td>7.09</td>
<td>18.90</td>
</tr>
<tr>
<td>GIS (satellite mapping of crop)</td>
<td>3.15</td>
<td>7.87</td>
</tr>
</tbody>
</table>

(12 missing data points. Sorted by 'essential' column.)
The most essential piece of information as far as the consultants are concerned is the cost effectiveness of the product, chosen by all 7 consultants. Six out of the 7 also felt that the range of diseases controlled by the product was essential as was the varietal disease resistance rating. The product's effectiveness was chosen by 5 out of 7 as essential and 4 consultants felt that the disease life cycle, disease level in the crop and the yield potential were all critical factors.

<table>
<thead>
<tr>
<th>Information</th>
<th>Essential</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost-effectiveness of product</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Diseases controlled by product</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Varietal disease resistance rating</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Effectiveness of product</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Biology, life cycle of disease</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Disease level in crop</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Yield potential</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Availability of product</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Cost per hectare</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Duration of effect</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Growth stage of crop</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Local disease pressure</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Tank mix compatibilities</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Weather forecast</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Current weather Information</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Previous treatments</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Recent past weather conditions</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Sprayer work rate</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Trials results</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Crop history</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Crop position in rotation</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Environmental impact of product</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Interpretation of diagnostic kit results</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Safety information about product</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Disease Identification photos/guides</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>GIS (satellite mapping of crop)</td>
<td>-</td>
<td>1</td>
</tr>
</tbody>
</table>

Information rated as important but not essential by 5 or more of the consultants was as follows: local disease pressure (6); the growth stage of the crop (5); recent past weather conditions (5); crop history (5); rotation (5); and environmental impact (5).
3.5 Whole farm decisions

Respondents were asked to list the ten decisions they felt were the most important that had to be made with respect to the whole farm. Their comments were sorted according to general categories and table 14 below shows the most frequently cited decision areas.

Table 14: Showing decisions farmers selected as important to the farm

<table>
<thead>
<tr>
<th>Decision Area</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input related decisions¹</td>
<td>170</td>
</tr>
<tr>
<td>Finance related decisions²</td>
<td>134</td>
</tr>
<tr>
<td>What cropping plan/rotation to adopt</td>
<td>103</td>
</tr>
<tr>
<td>What variety of crop</td>
<td>77</td>
</tr>
<tr>
<td>Machinery decisions</td>
<td>47</td>
</tr>
<tr>
<td>When to drill</td>
<td>37</td>
</tr>
<tr>
<td>Ensuring timeliness - of all activities</td>
<td>29</td>
</tr>
<tr>
<td>Labour - identifying labour requirements and making effective use of labour</td>
<td>28</td>
</tr>
<tr>
<td>Cultivation techniques</td>
<td>21</td>
</tr>
<tr>
<td>When to harvest</td>
<td>19</td>
</tr>
<tr>
<td>Soil management</td>
<td>10</td>
</tr>
<tr>
<td>(123 respondents)</td>
<td></td>
</tr>
</tbody>
</table>

¹Main Input decision areas

<table>
<thead>
<tr>
<th>Decision area</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray choice, rate and timing</td>
<td>53</td>
</tr>
<tr>
<td>Fertiliser choice, rate and timing</td>
<td>44</td>
</tr>
<tr>
<td>Weed control and herbicide use</td>
<td>27</td>
</tr>
<tr>
<td>Fungicide strategy and rates</td>
<td>27</td>
</tr>
<tr>
<td>Purchase of inputs</td>
<td>11</td>
</tr>
</tbody>
</table>

²Main Financial decision areas

<table>
<thead>
<tr>
<th>Decision area</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marketing &amp; sales timing</td>
<td>61</td>
</tr>
<tr>
<td>Budget/cash flow</td>
<td>18</td>
</tr>
<tr>
<td>Fixed costs</td>
<td>15</td>
</tr>
<tr>
<td>Capital expenditure</td>
<td>13</td>
</tr>
<tr>
<td>Purchasing</td>
<td>10</td>
</tr>
<tr>
<td>(1 missing data point)</td>
<td></td>
</tr>
</tbody>
</table>

Other categories not shown above include: Gross Margins (9), Fixed costs (8), Finances (6), Growth regulators (3), Pests (5), Balancing manpower and machinery availability; Assessing profitability of crops (10); Purchasing (10), environment (2); Safety (2); Storage (6); Advice/agronomy (8); Irrigation (3); IACS (3).

Taken individually variety choice appeared most frequently in the farmers lists although the number of categories relating to the financial aspects of the farm figure prominently as do the decisions relating to inputs. Decisions about the cropping strategy to adopt and the location and timing of drilling are also seen as important.

Table 15: Consultants important whole farm decisions

<table>
<thead>
<tr>
<th>Decision area</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticide choice/rate/timing</td>
<td>6</td>
</tr>
<tr>
<td>Fertiliser strategy/rate</td>
<td>6</td>
</tr>
<tr>
<td>Cropping/rotation</td>
<td>5</td>
</tr>
<tr>
<td>Variety</td>
<td>4</td>
</tr>
<tr>
<td>Machinery/labour planning</td>
<td>4</td>
</tr>
<tr>
<td>Financial planning &amp; marketing</td>
<td>4</td>
</tr>
<tr>
<td>Drilling date</td>
<td>3</td>
</tr>
<tr>
<td>Timing</td>
<td>3</td>
</tr>
<tr>
<td>Cultivation</td>
<td>2</td>
</tr>
<tr>
<td>(1 missing data point)</td>
<td></td>
</tr>
</tbody>
</table>

The decision areas selected by the consultants were similar to those of the farmers. Pesticide and fertiliser rates and timings were identified as important by all who responded to the question. Five of the 6 respondents chose cropping/rotation decisions and 4 chose variety choice, machinery and labour planning, financial planning and marketing.
3.6 Weather data and forecasting

Respondents were asked to identify sources from which they obtained weather data and forecasts.

<table>
<thead>
<tr>
<th>Info source</th>
<th>Farmers*</th>
<th>% of 133</th>
<th>Consultants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio/TV</td>
<td>113</td>
<td>84.96</td>
<td>6</td>
</tr>
<tr>
<td>Local weather information</td>
<td>94</td>
<td>70.68</td>
<td>6</td>
</tr>
<tr>
<td>Met office</td>
<td>68</td>
<td>51.13</td>
<td>2</td>
</tr>
<tr>
<td>On farm</td>
<td>27</td>
<td>20.30</td>
<td>1</td>
</tr>
</tbody>
</table>

(*6 missing data points)

A large number of farmers (84.96%) rely on the radio and TV and local weather information sources for their weather and forecasting data. While around a half use the Met office (51.135) only 20.3% say they get their information from on-farm sources. The pattern shown by the consultants is the same.

The latter figure is reflected in the low number of respondents who record their own weather data. As table 17 below indicates, the most frequently recorded information is daily rainfall, collected by 42 farmers. Min/max temperatures and wind direction are gathered by 18 and 15 percent of the respondents, again largely on a daily basis. Additional comments suggest that wind speed and direction are observed also as required prior to spraying.

<table>
<thead>
<tr>
<th>Weather data type</th>
<th>No.</th>
<th>% Daily</th>
<th>Weekly</th>
<th>Monthly</th>
<th>Not said</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>49</td>
<td>36.84</td>
<td>42</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Min/max temps</td>
<td>25</td>
<td>18.80</td>
<td>15</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Wind direction</td>
<td>20</td>
<td>15.04</td>
<td>9</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Windspeed</td>
<td>17</td>
<td>12.78</td>
<td>6</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Soil temps</td>
<td>9</td>
<td>6.77</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Humidity</td>
<td>9</td>
<td>6.77</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

(6 missing data points)

Four of the 7 consultants record daily rainfall, 2 min/max temperatures, soil temperature and humidity are recorded by only one person.
3.7 Sources of advice

One hundred and thirteen people said that they obtained advice from a crop consultant of one kind or another. Just over half (53.10%) of these said they used independent consultants, and 46% said they used agrochemical distributor consultants, there were single mentions of ADAS, MAFF and own information, 5 people employed more than one source.

3.8 Chemical supplies

Table 18: Farmers sources of chemical supplies

<table>
<thead>
<tr>
<th>Source</th>
<th>No.</th>
<th>% of 135</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buying group</td>
<td>70</td>
<td>51.85</td>
</tr>
<tr>
<td>Independently</td>
<td>50</td>
<td>37.04</td>
</tr>
<tr>
<td>Through representative</td>
<td>48</td>
<td>35.56</td>
</tr>
</tbody>
</table>

(4 missing data points)

More than one response was permitted to this question and many buy from a variety of sources, these are illustrated in the table below;

Table 19: Mix of chemical supply sources

<table>
<thead>
<tr>
<th>Source</th>
<th>No.</th>
<th>% of 135</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buying group alone</td>
<td>44</td>
<td>32.59</td>
</tr>
<tr>
<td>Independent alone</td>
<td>34</td>
<td>25.19</td>
</tr>
<tr>
<td>Representative alone</td>
<td>26</td>
<td>19.26</td>
</tr>
<tr>
<td>Representative and Buying group</td>
<td>15</td>
<td>11.11</td>
</tr>
<tr>
<td>Independent and buying group</td>
<td>8</td>
<td>5.93</td>
</tr>
<tr>
<td>Representative and Independent</td>
<td>5</td>
<td>3.70</td>
</tr>
<tr>
<td>All 3 sources</td>
<td>3</td>
<td>2.22</td>
</tr>
<tr>
<td>Total</td>
<td>135</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Over 10% of the farmers buy from a combination of chemical company representative and buying group sources, 5.9% buy independently and use a buying group and 3.7% buy independently and use chemical company representatives. A few (2.2%) use all three sources. Two farmers said they consulted with their local agronomist before buying independently.
3.9 Useful facilities

Respondents were asked which of a list of facilities they would find useful and to what degree they felt those facilities represented a saving of time and/or money, their responses are listed in table 20 below.

<table>
<thead>
<tr>
<th>Facilities</th>
<th>No.</th>
<th>% of 131</th>
<th>Large -med. savings</th>
<th>Med. - small savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Market information (e.g., crop prices).</td>
<td>108</td>
<td>82.44</td>
<td>75</td>
<td>26</td>
</tr>
<tr>
<td>2 Local trials results.</td>
<td>108</td>
<td>82.44</td>
<td>74</td>
<td>25</td>
</tr>
<tr>
<td>3 Variety information (e.g., NIAB).</td>
<td>108</td>
<td>82.44</td>
<td>63</td>
<td>38</td>
</tr>
<tr>
<td>4 Early warnings of unusual pests or diseases.</td>
<td>104</td>
<td>79.39</td>
<td>62</td>
<td>33</td>
</tr>
<tr>
<td>5 Information on the effect of weather on product effectiveness.</td>
<td>103</td>
<td>78.63</td>
<td>74</td>
<td>26</td>
</tr>
<tr>
<td>6 Tank mix compatibility information.</td>
<td>97</td>
<td>74.05</td>
<td>55</td>
<td>39</td>
</tr>
<tr>
<td>7 Accurate cost and availability data for products.</td>
<td>96</td>
<td>73.28</td>
<td>66</td>
<td>24</td>
</tr>
<tr>
<td>8 Price information on products.</td>
<td>95</td>
<td>72.52</td>
<td>66</td>
<td>24</td>
</tr>
<tr>
<td>9 Local weather information.</td>
<td>91</td>
<td>69.47</td>
<td>67</td>
<td>20</td>
</tr>
<tr>
<td>10 Reminders of pest/disease danger periods.</td>
<td>91</td>
<td>69.47</td>
<td>53</td>
<td>30</td>
</tr>
<tr>
<td>11 Facility to do financial 'what if' calculations.</td>
<td>90</td>
<td>68.70</td>
<td>57</td>
<td>31</td>
</tr>
<tr>
<td>12 Product dose response curves.</td>
<td>88</td>
<td>67.18</td>
<td>65</td>
<td>15</td>
</tr>
<tr>
<td>13 The ability to match the application of nutrients to field requirements.</td>
<td>86</td>
<td>65.65</td>
<td>66</td>
<td>17</td>
</tr>
<tr>
<td>14 Compiled or sorted independent information on product effectiveness.</td>
<td>84</td>
<td>64.12</td>
<td>66</td>
<td>14</td>
</tr>
<tr>
<td>15 'John Nix' type information</td>
<td>83</td>
<td>63.36</td>
<td>40</td>
<td>38</td>
</tr>
<tr>
<td>16 Rapid access to national trials results.</td>
<td>77</td>
<td>58.78</td>
<td>40</td>
<td>34</td>
</tr>
<tr>
<td>17 Changes in disease and variety resistance characteristics.</td>
<td>77</td>
<td>58.78</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td>18 Facilities for sorting and extracting relevant parts of the above information.</td>
<td>76</td>
<td>58.02</td>
<td>45</td>
<td>22</td>
</tr>
<tr>
<td>19 Manufacturers information / chemical company recommendations.</td>
<td>75</td>
<td>57.25</td>
<td>35</td>
<td>38</td>
</tr>
<tr>
<td>20 Facility for gross margins analysis.</td>
<td>74</td>
<td>56.49</td>
<td>39</td>
<td>33</td>
</tr>
<tr>
<td>21 Facility to cross reference data from different chemical companies.</td>
<td>68</td>
<td>51.91</td>
<td>32</td>
<td>31</td>
</tr>
<tr>
<td>22 Maps of your own fields with facilities to add in ditches, hollows etc.</td>
<td>66</td>
<td>50.38</td>
<td>22</td>
<td>40</td>
</tr>
<tr>
<td>23 Map based facility for recording weed locations.</td>
<td>65</td>
<td>49.62</td>
<td>25</td>
<td>40</td>
</tr>
<tr>
<td>24 Safety information.</td>
<td>65</td>
<td>49.62</td>
<td>20</td>
<td>44</td>
</tr>
<tr>
<td>25 Mapping of field and yield characteristics (e.g., GIS).</td>
<td>64</td>
<td>48.85</td>
<td>27</td>
<td>33</td>
</tr>
<tr>
<td>26 Mode of action of products.</td>
<td>62</td>
<td>47.33</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>27 Pest and disease simulation models.</td>
<td>56</td>
<td>42.75</td>
<td>24</td>
<td>30</td>
</tr>
<tr>
<td>28 Composition of formulated mixes.</td>
<td>55</td>
<td>41.98</td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>29 A facility to aid the collation of information on pest and disease research.</td>
<td>53</td>
<td>40.46</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td>30 Ability to integrate financial data from different software packages/files.</td>
<td>50</td>
<td>38.17</td>
<td>26</td>
<td>23</td>
</tr>
<tr>
<td>31 Information on seed availability.</td>
<td>43</td>
<td>32.82</td>
<td>4</td>
<td>42</td>
</tr>
<tr>
<td>32 A facility to identify and sort client information.</td>
<td>25</td>
<td>19.08</td>
<td>4</td>
<td>22</td>
</tr>
</tbody>
</table>

(8 missing data points)

The first 14 facilities are clearly popular with farmers and believed to be capable of producing reasonable savings of time and money. Facilities 15-21 are seen as interesting by over 50% of those responding but are more mixed in terms of their perceived ability to save time or money, with the exception of facility 18 which is seen by most as offering potential savings. Facilities 21-29 were selected by over
40% of the respondents but are either mixed in terms of perceived savings or seen as offering medium to small levels of saving. Table 21 below shows the results from the consultants questionnaire responses.

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Total</th>
<th>Large - med</th>
<th>Med. - small</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local trials results.</td>
<td>7</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Compiled or sorted independent information product effectiveness.</td>
<td>7</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Facility to do financial 'what if' calculations.</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Early warnings of unusual pests or diseases.</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Tank mix compatibility information.</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Product dose response curves.</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Changes in disease and variety resistance characteristics.</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Manufacturers information / chemical company recommendations.</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Variety information (e.g., NIAB).</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Accurate cost and availability data for products.</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Price information on products.</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Information on the effect of weather on product effectiveness.</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Rapid access to national trials results.</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Facilities for sorting/extracting relevant parts of above information.</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Composition of formulated mixes.</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Safety information.</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Map based facility for recording weed locations.</td>
<td>5</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>'John Nix' type information</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Reminders of pest/disease danger periods.</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>A facility to aid the collation of information pest and disease research</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Mode of action of products.</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Facility to cross reference data from different chemical companies.</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Local weather information.</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Information on seed availability.</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Facility for gross margins analysis.</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>The ability to match the application of nutrients to field requirements.</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Ability to integrate financial data - different software packages/files.</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Pest and disease simulation models.</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Maps of your own fields with facilities to add in ditches, hollows etc.</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Mapping of field and yield characteristics (e.g., GIS).</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Market information (e.g., crop prices).</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>A facility to identify and sort client information.</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Consultants and farmers have chosen many of the same facilities, 10 of the consultants top 14 facilities are the same as the farmers. The four additional facilities that consultants chose concern obtaining information on changes in resistance characteristics, manufacturers recommendations, access to trials results and sorting mechanisms. Those top slots were taken in the farmers survey by market information, local weather information, pest/disease reminders and field/nutrient mapping.
4.0 DISCUSSION

The purpose of this third survey was to validate and expand the user requirements identified in the first and second set of interviews, i.e. to:

- validate the key decision areas in arable farming and the facilities which might support this process;
- identify the information users require to make good decisions about the use of fungicides on winter wheat; and
- to identify the main farm decisions which potential users of DESSAC have to resolve.

The discussion will examine each of these three areas in turn in the light of the questionnaire results.

4.1 Validation of requirements

The main criticism of the earlier studies was the size of the samples and in particular the range of farm sizes they contained. This survey has elicited the views of an additional 139 farmers, 30% of whom farm more than 600 ha and 12% more than 1000 ha. The results, although self selected, should be seen as reasonably representative of the arable farming industry as a whole. It should however be noted that those who currently have computers are more likely to have responded to the survey as the DESSAC project is of potential benefit to them.

It is not surprising then that the percentage of farms with computers (75%) was slightly higher than observed in the previous surveys. The results do seem to support observations from earlier research that farms are becoming more computerised and that the majority of farm computers are capable of running Windows based software (85%). The farmers who responded seem, in general, to be using computer themselves i.e. they are not solely a tool of the administrative staff. The current uses of the computers are still mainly administrative with the majority of farmers using them for gross margins analysis (76%), farm records (74%) and accounts (72%). Fifty-nine farmers did however state that they used a crop management package, the most commonly cited was Optimix CMS (78%). The pattern of use i.e. several times a week, mostly during office hours and evenings supports the view that computers are employed as tools for normal farm management rather than for recreational or home use.

The decision areas which were most frequently chosen by farmers as important when growing arable crops were: choice of effective spray date (63%); choice of spray ingredient (62%); choice of variety (57%); fertiliser requirements (55%); and diagnostic decisions when faced with crop damage (55.47%). Support for each of these areas was essentially the same in each of the farm size categories. Each of the selected areas falls into the category of 'external information based, scientific' decisions which in UNG 2.0 were identified as potentially suitable for additional support. Scheduling and safety decisions (farm based information and non-scientific) were low on the list as was choice of distributor.
Most of the farmers who responded to the questionnaire use a crop consultant, either independent (53%) or from an agrochemical distributor (46%). The use of independent consultants is much greater than the previous surveys suggested. One possible reason for this may be the categorisation of agrochemical company consultants as independent, a situation which occurred several times during the face to face interviews and was only clarified on further questioning. The percentage of farmers in this survey who buy their chemicals independently and though buying groups is also higher than in the previous samples. The range of farm sizes used in the survey may have some influence on this as the proportion of farms in the 200-400 ha range who use distributors is less, and the proportion of those in the 0-200 ha greater, than expected given their distribution but the numbers are too small to be certain.

All 7 consultants who responded to the survey possess a computer which they personally use, 6 of which are definitely Windows compatible. This is a higher percentage than reported in the face to face surveys which might again be accounted for by the natural bias of the respondents mentioned previously. Their pattern of use differs slightly from the farmers in that 3 of the consultants only use their machines at evening and weekends. This may reflect the work patterns of the profession rather than indicate purely recreational use, as all the evening and weekend users report activities such as gross margins analysis, farm records and accounting. Optimix CMS was used by all 3 consultants who use a crop management package.

The decision areas consultants selected as important were very similar to those of the farmers with over half selecting choice of ingredient, fertiliser requirements, effective spray date and variety choice.

Key facilities
The facilities that farmers most frequently selected as being useful and capable of producing reasonable savings of time and money were:
- Market information (e.g., crop prices).
- Local trials results.
- Variety information (e.g., NIAB).
- Early warnings of unusual pests or diseases.
- Information on the effect of weather on product effectiveness.
- Tank mix compatibility information.
- Accurate cost and availability data for products.
- Price information on products.
- Local weather information.
- Reminders of pest/disease danger periods.
- Facility to do financial 'what if' calculations.
- Product dose response curves.
- The ability to match the application of nutrients to field requirements.
- Compiled or sorted independent information on product effectiveness.

To a large extent these agree with the recommendations made in the UNG 2.0, however the following differences were observed. The facilities:
- Access to information on chemical manufacturers specification data.
• Tools to support sorting, cross referencing and analysing of database records taken from UNG 2.0, were seen as interesting by over 50% of those responding but scored less well in terms of their perceived ability to save time or money.

Pest and disease prediction models was selected by over 40% of the respondents but were seen as mixed in terms of perceived savings. The only facilities suggested in UNG 2.0 which received low ratings from farmers in this survey were:
• Tools to support the integration and compilation of pest and disease data.
• Facilities to support mapping of field characteristics, yields, ditches, weeds etc.
• Information on seed availability.

Consultants favour many of the same facilities as farmers, 10 of the top 14 facilities are the same. Consultants were however more interested in information on changes in resistance characteristics, manufacturers recommendations, access to trials results and sorting mechanisms than farmers. Those top slots were taken in the farmers survey by market information, local weather information, pest/disease reminders and field/nutrient mapping - choices which seem to reflect the farmers financial and practical concerns.

4.2 Information required to make decisions about fungicide applications

Respondents were asked to identify the information they felt to be important and essential when making decisions about fungicide applications. In the event people tended to select more items for the essential column than for the one labelled 'important'! The top 3 essential items of information as far as farmers are concerned all relate to chemical choice i.e. the range of diseases controlled by a product (73%), its effectiveness (73%) and its cost effectiveness (69%). Other information areas selected as essential by over 50% of the farmers who answered the question were: disease level (67%); growth stage (62%); duration of effect (59%); weather forecast (55%); and tank mix compatibility (54%). Items which were considered important, but not essential, by over half those responding to the question were: current weather (65%), costs per hectare (65%), trials results (61%), recent past weather conditions (58%), environmental impact (57%), life cycle of disease (57%), and local disease pressure (53%).

The most essential pieces of information as far as the consultants were concerned are very similar, these were: the cost effectiveness of the product (7/7); the range of diseases controlled by the product (6/7); the varietal disease resistance rating (6/7); product effectiveness (5/7); disease life cycle (4/7) disease level in the crop (4/7) and the yield potential (4/7). The difference in emphasis on information and the choice of varietal resistance rating and yield potential perhaps reflect the scientific approach of consultants.

The results of this survey supports findings from horticulture (Parker & Phelps, 1994) that the type of local weather data collected on farms, and therefore available to incorporate into models, is fairly limited. Daily rainfall, min/max temperatures and wind direction are the most frequently collected types of information and are gathered by only 37%, 19% and 15% of farmers respectively. Windspeed and
direction are recorded during spraying periods. Most farmers get their weather data from the radio or TV (85%), or from local sources (71%). Little recording is carried out by consultants either, only 4 of the 7 record daily rainfall.

4.3 Whole farm decisions

The free text nature of the responses to this question introduced a subjective element into the analysis, in that each decision area was sorted into some form of category. In most cases this was a very straightforward process, but some areas, particularly those related to finance and strategic farm management, are less easy to pigeonhole. Some fairly clear patterns emerged from the data. The main decision areas (selected by over 25% of respondents) would seem to be: variety choice; marketing and sales planning; weed control and herbicide use; fertiliser choice, rate and timing; spray choice, rate and timing; rotation or where to grow the crop; when to drill; what cropping plan to adopt; cultivation and soil management; and financial planning decisions such as budget/cash flow, purchase, capital expenditure, assessing the profitability of the crop and controlling costs. Taken together the count for the financial decision 'category' received the highest number of items (79), variety choice second (76) and marketing third (61).

While the list does not highlight any decision areas that the project has not already considered it does underline the need for the DESSAC system to support or integrate tools for the financial management of the farm and for the more general management areas such as rotation.

5.0 SUMMARY

The results of the postal survey broadly support the findings of the previous surveys. More importantly however, the exercise, has served to focus and prioritise the earlier more general statement of requirements. There is now a clear order of priority for information for the fungicide module and additional information on the types of weather data that farmers can realistically provide. The focus of the broad DESSAC system seems to be appropriate although the need to support or integrate tools for the financial management of the farm and for the more general management areas such as rotation has been emphasised.
APPENDIX F:
DESSAC Workshop Report


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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Results of the First Phase
User Workshops.

Document UNG/4.0 - Draft

Decision Processes for Winter Wheat.
User Requirements for Future Decision Support Systems.

March 1996
User Needs Working Group

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EXECUTIVE SUMMARY

Between September 1994 and August 1995 interviews and postal questionnaires were used by the DESSAC User Needs Working Group to determine the user requirements for a DESSAC type system. The results of these activities are reported in UNG 1.0, UNG 2.0 and UNG 3.0.

A first draft of the user requirements statement was collated from the results. The next stage was to ensure that information within it had not been distorted in the translation process by checking again with potential users. A workshop format was selected as the most appropriate and effective forum for this activity. The planned workshop was also seen as a useful point at which to gain user feedback on the direction the Technical Working Groups ideas had been taking. The two activities; feedback on requirements and feedback on presentation ideas, were therefore linked and tied in with the need to inform the industry of the work that DESSAC is doing.

Seventeen potential users, without previous knowledge of DESSAC, took part in the workshops: 6 advisers from ADAS Lincoln, 5 farmers from Lincolnshire and 6 agrochemical representatives from Dalgety.

The user workshops consisted of:

- An introduction to DESSAC.
- Reading through and commenting on the general user requirements.
- Reading through, commenting on, extending and prioritising the requirements specific to fungicides for winter wheat.
- Identifying the information required for making decisions on fungicides for winter wheat.
- Examining and commenting on the design ideas presented by the Technical Working Group, using structured evaluation questionnaires and hands-on experience to enable to workshop participants to comment constructively on the demonstrations in the time available. The design ideas demonstrated and evaluated during the workshops were:
  - Disease advice, Spray cost and Growth stage screens.
  - Map based input and display system for field and farm information.
  - Encyclopaedic data presentation.
- Completion of a workshop questionnaire to evaluate the extent to which the workshop participants felt they had been able to comment during the workshop, and to assess their initial responses to DESSAC.

All participants seemed to like the idea of the system although its eventual existence and robustness was treated with varying degrees of scepticism. The farmers felt that the idea behind DESSAC i.e. bringing all the information together, was 'incredible'.

The information on the user requirements and on the stand-alone demonstrations that came from the workshops was valuable to both the User Needs Group and the Technical Working Group within DESSAC. A number of changes were seen to be necessary and are now being implemented within the project, and a further round of user workshops is planned for later in 1996.
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APPENDIX B  The complete set of overheads used during the workshops
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APPENDIX I  Questionnaire for combined WWFun screens.
APPENDIX J  Questionnaire for the map based input screen
APPENDIX K  Questionnaire for the Encyclopaedic data
APPENDIX L  Workshop evaluation questionnaire

Appendices are bound separately to avoid over-burdening those who don't require them.
1.0 INTRODUCTION

This document describes the results of the fourth stage of the user requirements analysis for the DESSAC project.

From its earliest days, the DESSAC consortium has been strongly supportive of a user-centred approach to its design process. The project employs a management approach which ensures that the potential end-users of the DESSAC system have a direct input to its content and presentation. The User Needs Working Group (UNWG) as the main focus of this activity is tasked with:

- defining the most important arable crop decisions;
- defining the information needed for optimal use of fungicides on winter wheat;
- identifying the major classes of user and their individual needs;
- evaluating methods of presenting information; and
- assessing the acceptability of prototype systems to users.

Between September and December of 1994 face to face interviews with potential future users of the DESSAC system were carried out (UNG 1.0 and UNG 2.0). These interviews were focused on the requirements for the DESSAC system as a whole and aimed to identify information needs, information sources, and the dynamics of decision making on individual farms.

In July 1995, the results of the face to face interviews were supplemented by a postal survey of Morley Research Centre Members. The purpose of this activity being to: validate and expand the user requirements previously identified with a much larger sample of potential users; expand on the requirements for winter wheat decisions; and identify the broader set of farm decisions within which DESSAC and the Winter Wheat Fungicide Module (WWFung) will have to operate. The results of the postal survey are reported in UNG 3.0.

The information from these three activities was analysed and collated in the form of the first draft of a user requirements statement. The next stage was to ensure that information within it had not been distorted in the translation process by checking again with potential users. A workshop format was selected to as the most appropriate and effective forum for this activity.

In parallel with and linked to these activities the Technical Working Group (TWG) had been developing ideas for the content and presentation of various components of the DESSAC system. The planned workshop was seen as a useful point at which to gain user feedback on the direction the ideas had been taking and so the two activities, feedback on requirements and feedback on presentation ideas, were linked.

The remainder of this document describes the procedures adopted during the workshops (Section 2.0) and summarises the feedback given to the project by the users on the user requirements (Section 3.0), the demonstrations (Section 4.0) and on the workshop itself (Section 5.0). The document concludes by identifying the lessons learned by this activity and outlining the future direction of the UNWG approach.

- 1 -
2.0 METHODS

2.1 Design

The purpose of the user workshops was fourfold:

1) To validate and refine the user requirements identified in the interviews and postal questionnaire.
2) To keep farmers and advisers involved in the design process
   - To make sure the system will be relevant and usable.
   - To make a reasonable sample of users feel the system is 'theirs'.
3) To gain feedback on the type of information DESSAC might present and also on the method of presentation it might use.
4) To publicise the work being carried out within the DESSAC project.

To achieve these targets the following requirements for the workshops were agreed:

- Each workshop should be small enough to allow each participant to make a contribution and to allow group discussions (a maximum of 7 people).
- There should be sufficient machines available for displaying the software so that each workshop participant could have some 'hands-on' experience (at least 2 machines, preferably 3 or 4).
- As well as information gathering, the workshops would serve as an opportunity to publicise the DESSAC project. Participants should therefore be given a short overview of the project and an opportunity to keep in touch with future developments within DESSAC.
- The workshop itself should be evaluated by the participants. This would determine whether participants felt that they had been heard and whether they had been given enough information to enable them to give useful feedback.
- The workshops should take place to coincide with the 'quiet period' for farmers and advisers - i.e. November to January.
- A cross section of the potential future users of DESSAC should be involved in the user workshops, and four main groups were identified:
  - Large Scale Farmers
  - ADAS
  - Consultants
  - Chemical Representatives
- The workshops were to be designed and run by HUSAT, who had the required expertise. System designers would also be involved as 'technical support', so that they could experience the user feedback at first hand.
- Demonstrators should be robust. Even though this was not a complete working system, and the users were made aware of this, it was considered important to avoid the possibility obviously wrong results, as this could well colour the users views.
- The workshops were to be kept to a maximum of three hours, to encourage farmers and advisors to attend.
2.3 Users

Three different workshops were carried out, on the following dates, and with the following groups of potential users:

- 7th December at ADAS, Lincoln. Afternoon session for 6 ADAS advisers
- 8th December at ADAS, Lincoln. Morning session for 5 Lincolnshire farmers
- 12th December at Dalgety - Technical advisers / Chemical representatives.

2.2 Procedure

The timetable for each workshop was as shown in Table 1 below.

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 min.</td>
<td>Welcome and introduction to project</td>
</tr>
<tr>
<td>10 min.</td>
<td>Comments on user requirements</td>
</tr>
<tr>
<td>15 min.</td>
<td>Requirements for the Winter Wheat Fungicide Module</td>
</tr>
<tr>
<td>5 min.</td>
<td>Tea/Coffee</td>
</tr>
<tr>
<td>15 min.</td>
<td>Priority of questions</td>
</tr>
<tr>
<td>20 min.</td>
<td>Information required to answer questions</td>
</tr>
<tr>
<td>1 hour</td>
<td>Examination of current design ideas</td>
</tr>
<tr>
<td>30 min.</td>
<td>Summary of views on design ideas</td>
</tr>
<tr>
<td>5 min.</td>
<td>Workshop evaluation questionnaire</td>
</tr>
</tbody>
</table>

The following is a description of the aim of each stage of the workshop, and a description of the tools used and method of presentation (e.g. questionnaire, group discussion etc).

2.2.1 Welcome and Introduction.

Before attending the workshop, each participant at the user workshops was sent a letter of invitation briefly explaining the aims of the workshop, as well as asking them to complete a pre-workshop task to bring with them. The letter and task are shown in Appendix A. The purpose of the task was to encourage the participants to think about their requirements before coming to the workshop.

On arrival at the workshop, each workshop participant was presented with a named folder, which contained the user requirements document that they were to comment on, as well as brochures explaining about DESSAC and HUSAT. This was both to make each participant feel welcomed and to give a little more background information.
For most people attendance at this workshop was their first introduction to the DESSAC project. In recognition of this fact, a brief introduction to the project, the participants, aims and timescales was given. There was also an explanation of why users such as themselves were a vital part of the evaluation process of the developing DESSAC system, and how the present workshop was part of an ongoing refinement and user requirements elicitation process that would continue for the lifetime of the project. It was stressed that their views were important and valuable, and would have a real effect on the project. The complete set of overheads used during the workshops are given in Appendix B.

2.2.2 Comments on User Requirements.
The workshop participants were then asked to comment on the DESSAC user requirements. The purpose of this activity was to validate user requirements previously distilled from the interviews and postal questionnaire and users were asked if there were any requirements that were missing or unnecessary. A copy of the user requirements document used is shown in Appendix C.

2.2.3 Requirements for the Winter Wheat Fungicide Module.
Following this activity participants were asked to concentrate on the area of fungicides for Winter Wheat. There were certain areas where very general and open ended answers had been given by users, and these were used to prompt more specific and in depth questions that the users would want to have help with from a system such as DESSAC. To help in this process, an example of a specific question was read out (this example is shown in Appendix D). Then the group as a whole discussed and identified other specific questions they would want to ask. Responses were recorded by HUSAT staff.

After the set of questions were identified, the group was asked to prioritise them. Each decision area that the group agreed they wanted help with was given a rating according to its perceived importance. The workshop participants then discussed what information they thought would be needed to make these key decisions in the area of winter wheat fungicides.

2.2.4 Examination of current design ideas.
Participants were then given an introduction to the design ideas they were to evaluate and reassured that their views were valuable and would have an effect on future design. It was stressed that the elements they were to see were in no way the final DESSAC system itself, but only small, discrete parts to demonstrate possible design ideas and allow for comments, and that in some cases, the parts would not be fully functional; they were being shown elements at such an early stage to allow their comments to have a real effect on the emerging system.

The participants were then divided into two groups. Each group was shown a part of the DESSAC demonstration software, then the two groups swapped over. In this way, the potential effect of order was taken into consideration during the evaluation. The small size of the groups also allowed each user to have a say.
The design ideas demonstrated and evaluated during the workshops were:
- Disease advice, Spray cost and Growth stage screens
- Map based input and display system for field and farm information
- Encyclopaedic data

The User Needs Working Group in collaboration with the Technical Working Group had previously identified a list of questions which would provide useful feedback for system development. These and more general usability topics were incorporated into questionnaires for use during and after the demonstrations. Also included in these questionnaires were a number of more open ended questions, to allow the workshop participants the freedom to express their thoughts and feelings about the systems utility and usability.

A separate questionnaire was created for each area of the demonstrations, enabling questions specific to that area to be asked, and allowing the participants to answer questions on one area before going on to the next.

The questionnaires for each area were administered according to the preferences of the participants i.e. they were filled in either individually or as a group or by an evaluator who would read out the questions and then take notes. The questionnaires used for this activity are given in Appendices F to K.

2.2.5 Summary of views on design ideas
After the design ideas had been demonstrated, the main comments and suggestions for improvements were presented back to the participants, both to show them that they had been heard, and also to allow them to amend any points that had been misunderstood or not fully recorded. The participants were then thanked for taking part.

2.2.6 Workshop Evaluation Questionnaire.
The final task of the workshop was the completion of an anonymous workshop evaluation questionnaire which asked the participants to evaluate the session in terms of the following:

- Whether they had received appropriate and sufficient information on DESSAC.
- Whether they had been given enough time and information to allow them to comment usefully on the design ideas.
- Whether they would find the eventual DESSAC system useful to them personally.
- How much money they would be willing to spend on a DESSAC type system.
- Whether they would like to be kept informed of further developments within the DESSAC project (this part of the questionnaire was on a tear-off strip that could be returned separately from the main questionnaire, to maintain confidentiality)

This workshop evaluation questionnaire is shown in Appendix L.
3.0 USER REQUIREMENTS RESULTS

The purpose of this section is to present the results from the user requirements section of the Workshop, as described in Sections 2.2.2 and 2.2.3, in a form that is useful for system designers and other project members to use.

3.1 Validation of user requirements

As part of a continuing refinement process, users were asked to look at summarised versions of the user requirements document and to make suggestions for amendments or additions. These comments were recorded on the requirements documents themselves and collected for analysis. The changes suggested by the groups have been incorporated into a new version of the user requirements statement which is published separately as UNG 5.0 and is not presented within this report.

3.2 Information required to make decisions about winter wheat.

During the workshop, farmers and ADAS advisers were asked to give their thoughts on what would be the most important and useful information to have access to when making winter wheat decisions. These sessions were very successful and this document provides a summary of the groups responses. Appendix E contains the complete list of issues raised in the discussion groups.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Farmers</th>
<th>ADAS Advisers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Which chemical works best?</td>
<td>Cost-benefit analysis</td>
</tr>
<tr>
<td>2*</td>
<td>What rates, effectiveness if spray under X conditions?</td>
<td>What impact will tank residue have on next crop(s)</td>
</tr>
<tr>
<td>2*</td>
<td>Alternative tank mixes</td>
<td>Environment and Safety, label and any extra legal.</td>
</tr>
<tr>
<td>3</td>
<td>Finance. Impact on Gross margin</td>
<td>Tank Mix, general</td>
</tr>
<tr>
<td>4</td>
<td>What are future implications of a decision - cost.</td>
<td>Where did this information come from - validation of source (need confidence in the information).</td>
</tr>
</tbody>
</table>

*Both groups identified two issues which ranked equally in second place

After an initial 'brainstorm' where all the groups ideas were listed, each group was asked to rank the main headings in order of their importance to the decision process. Table 2 above shows the areas each group identified, and the ranking they were given. The complete list of topics under the main headings is provided at the end of this document.

Farmers were most interested in what, when, and how much to spray. First ranking went to the question 'which chemical works best', followed by 'what rates should I use and how effective will it be under these (specified) conditions and also 'what will the best tank mix' be. Third and fourth rankings were related to finance, that is what
would be the present and future cost implications of a decision. In essence, the farmers want information to help them identify first, what is the best thing to do, then whether this decision will be cost effective, both now and in the longer term.

In contrast the ADAS advisers placed financial issues higher in the ranking, with the first place going to cost-benefit analysis. They are confident about which chemical to use and when but would like more information to help them decide if it's the most cost effective choice for their client. Next, jointly ranked second, they were interested in help with planning a complete spray regime, trying to minimise the flushing of chemical tanks between sprays, and having information on the environment and safety issues involved, both from a legal and practical viewpoint. Thirdly they wanted information on possible tank mixes, both recommended and possible (for instance, it may not be recommended, but it won't sludge out). In fourth place, the advisers wanted to be able to inspect the information that the system relied on when making recommendations, to check for themselves that it was valid.

In summary, while the topic headings chosen by the two groups are similar, the emphasis they place on them is different. Advisers obviously aren't that desperate for information in areas that represent their speciality, i.e. chemical choice and application but the farmers however are. The advisers, on the other hand, would rather have help with general logistics and information that gives them added value in their clients eyes. It could be said that the farmers were more interested in acquiring support with the central issues, whilst advisers are more interested in support for the more peripheral ones.
4.0 DEMONSTRATION RESULTS

The purpose of this section is to give the results of the demonstration part of the workshops in a form that is useful for system designers and other project members to use. The complete tables of results are available from HUSAT if required.

The comments and suggestions provided by the participants are presented screen by screen and organised into the following topics:

- General issues relating to general usability and the perceived advantages and disadvantages of the screen
- Navigation issues relating to the ease with which the user managed the dialogue
- Display issues relating to the actual look of the screen
- Content issues relating to the functions and facilities provided
- A list of additional information identified by participants
- A list of additional facilities identified by participants

Of all of the participants in the workshops only two people had ever used anything of a similar nature to this program. One adviser mentioned 'Distrain', which has a disease assessment guide, and one Agrochemicals consultant mentioned a weed programme called Agroplan.

The three demonstrations presented to the users were:
Disease Advice, Spray Cost and Growth Stage Screens
Although all related to the design of the Winter Wheat Fungicides Module, these three screens are dealt with separately below as each focused on a different aspect of decision support each generated a considerable ammount of user feedback. The Disease Advice Screen

- SAM HELP HERE -

Map-based Input screens
A set of screens designed to illustrate a map-based method of navigating through farm data. Clicking on the image of a field displayed information associated with that field and selecting an item from a list of data e.g. crop names, highlighted all fields currently growing that crop.

Encyclopaedic data presentation screens.
A set of screens illustrating a method of presenting encyclopaedic data based on the html approach used on the World Wide Web and accessed through browsers such as Netscape. Users selected 'hotlinks' or highlighted words or pictures to access additional information on that topic.
4.1 Disease advice

4.1.1 General Issues
The participants listed a number of advantages of using this screen. They were:

- The speed of mouse input
- The image of professionalism (presentations to farmers)
- The record keeping ability inherent in the system
- The reduced possibility of missing out a factor when making a decision
- The possibilities for pre-planning and training
- The ease of information retrieval compared with a paper-based system

On the negative side, one of the Agrochemical consultant groups felt the method was slow and not easily adapted to the mobile working environment e.g. didn't fit into a filofax for use in the field. They felt that the system was trying to do too many things at once, and should either be office or field based. In their opinion it was better as a preparation tool than an 'in the field' decision tool. The preparation work takes place in early spring when there is time for discussions. During the season they are too busy to use a system like this and are only able to 'tweak' decisions they have previously made. One of the adviser groups felt the possibility of the software overlooking issues lessened its appeal. The Agrochemical consultants also expressed concern that the system might suggest a chemical that the user did not have access to.

4.1.2 Navigation Issues
There were some problems with navigation and a number of participants expressed the need for 'cancel' and 'go back' buttons.

Farmers and advisers felt that they would like the facility to 'page up' and 'page down' when entering a lot of data. They would also like to be able to search for specific pages of information or details on specific fields or blocks.

4.1.3 Display Issues
While most thought it looked simple and easy to use there were a number of suggestions for improvements. Several participants thought the window should be larger and make use of a bigger font size, particularly for the title. They also felt that the window looked sparse and unappealing and needed more logical structuring e.g. start with a field or selection of fields, then move onto the crop.

One adviser said there should be more labelling of the information being shown and one of the agrochemical consultants said that he expected each disease to be highlighted.

4.1.4 Content Issues

Being able to group fields and enter data for a whole group
People from all user groups expressed the wish to be able to select 'blocks' of fields as well as having the ability to work with individual fields. The grouping facility would have to be able to cope with a number of different grouping parameters, e.g.
variety; 1st or 2nd cropping, drill date, pre 31/32, pre flag, weed cover, position, soil type, etc.

The ability to select a number of fields based on defined criteria, or a number of defined criteria, e.g. variety and 2nd cropping and then enter the data for these fields as a group was a basic requirement. One farmer identified the need for certain fields to be in different 'blocks' for different criteria (so a field might be in one block for disease and another for weeds). Agrochemical consultants said they may want to block on a particular farmers fields as well.

Entering disease levels
Advisers and agrochemical consultants both felt that the labels 'none', 'some' and 'lots of disease' were not specific enough. Agrochemical consultants would prefer to enter the % of leaf area covered by disease. One adviser suggested that there should also be somewhere to enter the youngest leaf that has the disease.

All groups agreed that treatment threshold levels should be identified (8% and 30% are the most commonly used). The system should flag when the level of a disease is above a threshold (one farmer suggested using green for okay (no risk), orange for be aware (medium risk), and red for definitely spray (high risk).

All groups agreed that a greater level of detail and help should be available to identify what the level of disease is, in pop-up windows, if requested. Farmers suggested pictures or fields, so you could identify the picture that is closest to your field, and have the data associated with that transferred.

Showing disease progression
One farmer and one Agrochemical consultant expressed a wish for a system that could show a disease moving across the country, or across an individual field, so that the progress could be tracked.

Entering data
All participants were keen to stress the need for the system to re-use data entered elsewhere (e.g. either within DESSAC or another system, such as Optimix). Existing data should automatically be entered for the user in the appropriate places.

For farmers, a major benefit was perceived to be the ability to enter data on the whole farm without changing screens (This presumes the user can enter data on different fields, blocks of fields, varieties etc. and store it for later use.)

It was suggested that the system should request the minimum amount of data it required to operate and leave additional information input to the users discretion.

One farmer very strongly expressed the need for a system that presented the user with the minimum of information at first, but was capable of delivering greater and greater detail, a 'pyramid' of information, with only the top presented initially.
There are some diseases (e.g. septoria) which are always sprayed for even in the absence of visible indicators. There therefore has to be some way of entering this information into the system.

**Default values**
Participants were asked what defaults they would expect the system to use. It was suggested that in general the system should default to the last set of inputs. On the disease level selection it was suggested that the absence of a value should be taken as an indication of no disease.

4.1.5 Additional information
A number of participants suggested additional information which they felt would be useful if displayed on this screen. The information is:

- Current date (to be saved with the data file for later comparisons)
- Drilling date (e.g. for calculating GS 32).
- Identification of the person who entered the information.
- Field area (so that total cost and field cost can be calculated).
- Growth stage.
- Canopy status.

4.1.6 Additional facilities
- 'Cancel' and 'Go back' facilities
- 'Page up' and 'Page down' facilities and related functionality
- Facility to search for specific pages of information or details on specific fields or blocks
- Ability to select 'blocks' of fields by variety; 1st or 2nd cropping, drill date, pre 31/32, pre flag, weed cover, position, soil type, etc.
- Ability to enter data 'en masse' for a block.
- Ability to move information on the screen e.g. date, etc.
- Ability to enter all the farm data at once then to page through and select data. Will also need an index to choose information from.
- Ability to select a number of fields based on defined criteria, or a number of defined criteria, e.g. variety and 2nd cropping
- Ability to enter the % of leaf area covered by disease
- Help to identify the level of disease
- Ability to enter the diseases which are always sprayed for.
- Ability to transfer ratings just by clicking on what you want (Farmers)
- Show more diseases
- Display of the level of risk involved (ADAS).
4.2 Spray cost

4.2.1 General issues
Despite a number of problems all participants felt that this screen was potentially useful. The farmers liked its simplicity, the advisers liked the visual representation of the information, and the agrochemical group liked the clarity of display and the ability to model their ideas. The graph was seen to be the most useful part of the screen but there was considerable confusion as to the purpose of the other areas. The graph was seen to be useful because:
- It provides a description of cost benefits and validation of why the farmer should spray (ADAS).
- It allows the farmer to have more input to the decision (ADAS).
- The graph showing margins over spray costs provides information that usually has to be estimated (ADAS).
- It cuts out a lot of books (Dalgety).
- Information is more up-to-date (Dalgety).
- It provides a more exact account of the effects of delaying a spray (Farmers).
- Gives a clear indication of what to adjust and when to change chemicals (Farmers).

The Dalgety groups felt that it would be more useful if it allowed access to ARC trials information and others for comparison of results. Overall the graph was seen as a good idea although the presentation needed some moderation as discussed in the next section.

On the negative side farmers initially had no idea of what this screen was showing them, the advisers and Dalgety groups were also somewhat confused. They all seem to have expected to select a spray type, and manipulate the different options before looking at this type of screen. All groups found the screen somewhat difficult to use. The main disadvantages of this screen were seen to be:
- The cost (Farmers).
- The farmers might have it (ADAS).
- It might overlook a factor (ADAS).
- It makes the decision for you (Dalgety).
- It might suggest a product they don't supply (Dalgety).
- It and might not have trials for a product they do supply (Dalgety).

Farmers said that the graph screen needed the most attention paid to improving it.

4.2.2 Navigation issues
Many participants found going forward simple, but going back to the previous screen hard.

4.2.3 Display issues
One of the key display issues raised by the participants was the crowded nature of the screen e.g. too many options, too much on the screen, cramped in the middle.

Graph
The general consensus was that a graph was a good way to display this information, but that a bar chart or histogram would be useful as well. One user from Dalgety
suggested that a bar chart with a tool bar would be best, so the output could be customised. The graph display was however felt by many to be unclear particularly for those with colour deficiencies. There was also some confusion between the functions of different parts of the screen.

The labelling of the x-axis, i.e. the use of 1/4, 1/2 as labels, was felt to be unclear. Several people suggested that would be better to use 0.25; 0.5; 0.75 and 1 for denoting rates, particularly as the display employs the same format for dates e.g. 1/3, meaning 1st of March.

An adviser said he would rather see increase in spray cost as a horizontal line, and have margins shown against this.

There was confusion among all group as to what best, average and worst case referred to. At first it was thought that the worst case was what would happen if you did nothing, the average case was what would happen if you did something, and the best case was what would happen if you did everything. The way it was displayed made people think that this range was within their control, and they could select one of the lines, and follow a course of action that would follow that line.

There was a consensus that a better method would be to show the average case, and then have an error bar coming from that line at various points showing the standard deviation and spread. Also it should be made clearer that the graph related to trials results. Standard deviation was also mentioned by a farmer, saying he would rather have SD than the range. Figures given relating to the graph should give the average as a default.

Everyone preferred the margin over spray costs graph to the other two graphs. This was seen to be the industry standard. One farmer stated that what was wanted was the effect it had on the final figure, not the individual spray cost. Farmers work on the profit figure from spraying, not the loss from not spraying. Also one agrochemical representative said that there should be an opportunity to specify the full spray cost, including a fixed cost element. Gross return from spraying was seen as possibly useful by one farmer and one person from Dalgety.

Suggestions for improving the display were:

- Box the graph off from the rest of the display
- Use more subtle shading.
- Get colours on key closer to colours on graph
- Use thicker lines
- Use better colours
- Bring down format options into boxes.
- Increase font size.
- Cater for users with colour blindness
- Put titles on the axis
- A grid that turns on and off, to make it easier to follow the curves to the axes.
- Markers to indicate the most relevant information
- Optimal dose shown by a cursor/indicator /highlighter
Labels
Farmer felt that the label 'Dose half rate' should be used rather than 'Dose half'.

One adviser and one Dalgety user said that the label 'spray type' should be changed. The adviser said change it to 'chemical name' and Dalgety said change it to 'product' or 'product choice'.

There were some comments from advisers and farmers which suggested that an option to display in acres or hectares will be required.

4.2.4 Content Issues
There was some confusion as to the meaning of some of the facilities. In particular most groups were not sure what 'expected future sprays' was for. The ADAS group thought this option should be removed from the screen. In addition one Dalgety group felt that the dose and application sections weren't clear enough.

Time representation
Participants were asked what format they would like to time represented in and the following suggestions were made:
- Days
- Date
- Leaf emergence
- Growth stage (although GS relates to date and leaf emergence)

ADAS groups, one farmer and two Dalgety participants felt that weeks after emergence was not a good parameter. ADAS thought that GS or date should be used instead. The farmer said that the system should be able to tell him the weeks from emergence based on today's date. One of the Dalgety group was unclear as to whether 'emergence' referred to the crop or the disease. He felt the growth stage was more relevant.

Spray Volume
One farmer said the spray volume should show more detail, i.e. per what? Another farmer said that the litres of water volume recommended was not what he would use, and he would want to be able to change this. One Dalgety group asked who had decided the spray volume, and said he would want to be able to fine tune this to his own needs.

Making changes
The ability to change variables was required by several of the farmers. The effects of making changes were also not well understood and hard to see e.g. the effect of changing the date of spray. They also wanted to be able to change the fungicide and see its effects.

They also wanted to be able to ring the dates they wanted, and fix them.

Product choice
The use of active ingredient rather than product name was suggested by both Dalgety and farmer participants. Product names that contain that ingredient, or choice of products with mixes should then be available (e.g., Asset) for selection.
Spray dates information
Advisers were confused about the spray dates information. Also there was no indication of when the last spray went on.

Spray now
Advisers and farmers were confused by 'spray now'? Why have it and what does it mean, is that today, in the next 3 days? One adviser said would want to be able to enter some expected future date, not necessarily now.

Number of spray applications
One farmer and one agrochemical consultant commented on the number of spray applications, wasn't sure if that was what had been or would be sprayed.

Expected future sprays
There was some confusion as to the purpose of the 'expected future sprays box'. Several people were not sure what its purpose was, another thought it related to knockback or persistence. One adviser said expected future sprays was of no use because if they miss the spray date they'd expect products and rates to change. One agrochemical consultant said it might be best to change the title to read expected future spray dates. An adviser said remove the expected future sprays and replace with an option to look at what would change if they sprayed in 10 days, 20 days etc.

Trials data
The farmer groups were a little unhappy with the use of trials data. They felt that the information would only be useful if there had been prior sorting of the trials data in some way (to make sure only relevant trials were included i.e. local, similar soil type, etc.). Farmers would want to know background information on the trials so that they could decide whether or not to take them into account. The ability to remove trials they were unhappy with was suggested. One farmer felt that the information would not be useful unless it also took into account data from his own field records.

Tank mixes
There was some interest in the way that this system would cope with tank mixes and how the use of a tank mix would be reflected in the curve. One farmer stated that the system would have to cope with mixes.

4.2.5 Additional information
Advisers suggested that other information should be shown on this screen, including soil type, yield, variety, field area and cost per field.

Where a half rate was recommended, farmers and advisers felt that more information should be given such as what a half rate was in litres per hectare, and where the figure came from (i.e. was it half of the manufacturers recommended dose?). Costs should also be given, and this should be per hectare as well. These figures depend on the cost of chemicals, so the source price that the calculation is based on should be shown, and adjustable if necessary. One farmer stated that
prices would have to already be in there, he would not want to spend time entering the information.

More than one farmer said that an explanation of dose and application date changes was needed. They would also like to see the system compare the efficiency of chemicals at various rates of disease.

One farmer said he would want to decide rate (click on graph where want to do) - then have prices and dose etc., all on one screen.

One agrochemical consultant said that he would like a global figure for cost and would like to be able to calculate the total amount of fungicide needed for a given farm.

4.2.6 Additional facilities
- To be able to enter days/date etc. into the dose and application date section (Farmer).
- Show current date on the screen (All).
- Allow access to ARC trials information (Dalgety).
- Go back to the previous screen (All).
- A bar chart or histogram option (All).
- Show the average case with an error bar showing the standard deviation instead of the three lines.
- An option to display in acres or hectares.
- Facility to show time as either days, date, leaf emergence or growth stage or more than one.
- Facility to change litres of water volume.
- Access to product names or mixes that contain a given ingredient.
- Access to background information on trials.
- Ability to cope with tank mixes.
- Facility to compare efficiency of chemicals at various rates of disease.
- Option to overlay grid over the graph.
- Display of source and price of chemicals and ability to adjust it.
4.3 Growth stage screens

4.3.1 General
After overcoming an initial confusion all participants thought they would find this screen useful. Farmers particularly liked the idea that they could use it to plan spraying around their skiing holidays! The ADAS group said they could use the data to support their discussions with farmers. The farmers and Dalgety groups said that although they used this type of information they currently have no means of displaying it all at once. Other advantages of this screen were seen to be: saving paper; reducing the need to read trials results; being able to compare product timings and effects on margins and disease levels; the ability to manipulate choices and view the outcome before making a decision.

On the negative side farmers and ADAS groups were nervous about trusting the system. They felt they needed to understand exactly how the system was making its decisions and what information it was basing them on before they would feel comfortable with it. The Dalgety group were concerned that it would take a long time to learn and use and would therefore lose its advantage over existing manual methods.

While the concept was generally accepted and approved there were a number of difficulties with the display and content which are detailed in the sections below.

4.3.2 Navigation
There were no comments on navigation during the demonstrations of this screen.

4.3.3 Display

Wheat plant graphics
There were a number of problems with the wheat plant graphics displayed on this screen. Participants were either of the opinion that they should be made more realistic to emphasise the growth stage or more stylistic to display the extent of the disease more clearly. Participants also suggested that the colours used to indicate disease could be made more easily distinguishable from one another. One ADAS adviser suggested that the graphic should distinguish between disease and natural senescence.

Disease level bars
The bars showing the levels of disease were seen by both farmers and ADAS advisers as 'a bit of a game'. Although they said would prefer alternative methods of displaying the information they didn't suggest any.
Preference for some form of graphical display was indicated by one of the farmer and one of the agrochemical groups.

Dates and growth stage
There were several comments about the use of dates and growth stage numbers. Several people wanted to see the date and the growth stage number together on the screen, preferably on the x axis and with the three main stages highlighted. One adviser group also felt that it would be useful to be able to set up their own dates.
Labelling
The font size was generally considered to be too small and the use of a bigger title was suggested. One adviser said that more labelling was needed to help the first time user understand the purpose of the screen.

4.3.4 Content
The link between this graphic and the graph screen was not clear to some of the advisers and farmers. One adviser felt that a better label on the calling button might have helped e.g. 'justify why this is the best yield' rather than simply 'Justify'. Participants also suggested that the information from the graph which related to this screen could be repeated or made available e.g. variety, field, block, etc.

The representation of time was also an area which caused difficulties for participants. They were unsure as to where they were in relation to the timescale on the display i.e. what had already been done and what was planned. Several people suggested that the screen could operate in two modes, a 'budgeter' mode, where they could manipulate possibilities, and a 'real' mode, where they could see what they'd actually done. Some clear means of distinguishing between the two would be required.

More information on the relationship between yield and disease control was required by some farmers. It was also not clear to some whether the potential yield was based on the drilling date or the present position.

Several comments related to the accuracy of the system. Participants weren't convinced that it took account of all the relevant variables e.g. variety, disease, rate of disease etc. One adviser commented that the system was working from an optimum, and needed to be related to disease pressure. The Dalgety group were concerned that the focus was solely on the margin and suggested that some farmers are also interested in the look of the field. There is a comfort factor involved. They therefore need to know about such things as mildew pressure. They felt that there was not enough risk assessment in the present system.

Supporting 'what if's'
A number of suggestions were made as to the means by which different scenarios could be compared. One person suggested 'stacking up' windows of previous options, another suggested being able to go backward and forward between different pages. It was generally felt that previous choices should be stored rather than discarded.

To support this type of activity one farmer thought that the arrows should leave a 'shadow' behind them when they were moved, facilitating a return to the previous value. A trace of the previous gross margin calculation might also be useful.

The default position was generally agreed to be the 'optimum' calculated by the software taking into account knowledge about previous sprays, level of existing disease damage etc. Several people requested an 'optimise' button which would automatically calculate the optimum on selection. Exactly what would be optimised was not clear e.g. global optimisation or the dose/timing of selected products?
Several users were confused by the bar chart on the right e.g. one person thought it might work on the previous fungicide selection. A number of suggestions were made for improving its usability, these were:
- Remove yield loss from the top of the chart.
- Display the gross margin.
- Allow the user to specify the yield required by adjusting the bars with the mouse. The rest of the screen should adjust automatically to show the required spray dates etc.
- Make the bars easier to distinguish from one another.

A number of requests were made for additional information, these were:
- Use both growth stage number and date on x axis (All).
- Current date should be displayed somewhere on the screen (All).
- Field name, size and soil type (ADAS).
- Financial table, showing yield loss and margin (Dalgety).
- Name of current chemical (Farmers, ADAS).
- Relevant information from previous screen.

The following additional functionality was requested:
- The ability to perform a universal search on any criteria (Dalgety).
- The ability to be able to select on drill date and variety (Farmer).
- The ability to click on an arrow indicating a previous spray and pull up the details of that application (Farmer).
- An 'Optimum' button. Selecting this option would present the optimum rate and timing of sprays (Farmer).
- Better help facilities e.g. drop box with explanation of arrows (ADAS).
- An 'Undo' button to return to the previous settings (Dalgety).
- Forwards and Back button (ADAS).
- Automatic generation of growth stage number with ability to update it. It was suggested that weather data could be used to predict crop emergence.
- The ability to select different chemicals and see the effects of toggling between them.
- The facility to print out information, especially spray cost and grain value.
- The facility to save the screen information as a file (Dalgety).
- Use of very localised models based on local information (Farmers).
- A means of identifying between 'budgeter' and 'real' modes of use.

Additional suggestions were made, these were:
- Remove the 0 from the fungicide rate as no one would use it (Dalgety).
- Remove the fixed limit on the fungicide applications (ADAS).
- Change plant graphic.
- Change bars showing previous position effects (disease level bars). Instead show different screens to allow comparisons to be made.
4.4 Map based input and display system for field and farm information

4.4.1 General Issues
The purpose of the map display was not immediately obvious to the users, some thought it was a general purpose mapping system, others a data retrieval system and some a method of showing field cropping plans. However few people had difficulty operating the interface, the main problems were caused by labelling and display characteristics which are discussed separately below. While none of the Dalgety group had seen anything like this tool previously, a few of the ADAS advisers and all of the farmers had previously used either Farmade or Optimix.

Most participants liked the idea of graphically representing the farm and thought the farm map idea was clean, appealing and more easily updatable than a paper format. It gave them the ability to store, access and edit information easily and they liked the ability to use colour. Almost all participants wanted access to both lists and the map display.

On the negative side the maps lack of portability was felt to be a disadvantage. Participants were also unhappy with its legibility, the inability to zoom and the level of detail. Having made these points however, the farmer groups were concerned that the DESSAC system might be re-inventing Optimix's mapping program. The type of facilities that most wanted, e.g. zoom, background, etc. are apparently already available in this software.

The majority of participants said the map/farm idea would be useful to them for the following reasons:
- Rotation planning/crop records (Farmers).
- IACS form filling (Farmers).
- For showing advisers the location of fields on big farms (Farmers).
- To help identify locations of individual fields. (ADAS).
- Avoid missing fields out, checking previous spray dates. (ADAS).
- Visualises the farm (ADAS).
- Easier to show farmers (Dalgety).
- Easier than current paper based versions (Dalgety, ADAS).

4.4.2 Navigation
All of the farmers and most of the ADAS group found it easy to locate the information once they knew how it was structured. A few of these groups felt they would like to access the information from the field name in the list as well as from the other routes. One of Dalgety groups wanted the top level windows to list all the available data which they could then choose to display in a variety of different ways.

The Dalgety group wanted to be able to look at 3 or so sprays at a time as there may be many types of spray in a single application. Farmers felt that it would be more useful if a two tier selection was possible e.g. wheat after wheat, wheat after OSR, etc. One group also felt that they would like unnecessary information to be removed from the screen when not in use. For example they would like to be able to click onto one crop e.g. winter wheat and then be presented with only winter wheat fields and winter wheat information.
4.4.3 Display
The size of the map was felt to be too small by several groups as was the size of the typeface. Others suggested that the colour and contrast could be improved to make it easier to see the field boundaries. An outline was considered to be sufficient with colours used to show current crops. The date should be shown somewhere to allow them to compare several years data. One farmer group felt that the size of the screen would make a big difference to the maps usability. The Dalgety groups wanted to know the names of fields growing particular crops.

There were consistent difficulties with some of the terms used. No-one was familiar with 'Dismiss' and most opted to change this to 'Close'. There was a feeling that the program should employ the terms they were already familiar with in Optimix etc. The headings 'Crop data' and 'Field data' also generated some confusion. Each group listed its understanding of the type of information they would expect to find under those headings and a consensus would appear to be:

**Crop data:**
Generally above ground information and data about this year only e.g. variety, cultivation's, drill date, applications (dose, active ingredient & date of application), spray information (product, quantity, problem, field inspection sheet, recommendation sheet, wind speed and direction and all legal statements), etc.

**Field data:**
Generally below ground and historical data e.g. field name/id, size, height above sea level, environment of field, warm or cold aspect, fertiliser data, pH, NPK levels, soil analysis results, drainage maps, yield maps, crop, cultivation's, varieties - click on to show on map or in another window. Lists may be better for some people.

4.4.4 Content issues
Participants were asked the type of things they expected to see on a map of this type. There were some differences in the types of answers that were given. Some farmers and ADAS advisers were keen to see a high level of detail (e.g. OS 1-10000 scale showing ditches, buildings, etc.) both within the farm area and on the farm borders. This degree of detail was felt to be useful when making spray decisions and essential if a link to GMS information was foreseen. Others were happy to use basic field and crop data. Dalgety seemed quite happy to use a rough outline as this avoided the problem of deciding whether the farmer or adviser should purchase the OS map. The ability to overlay maps of different levels of detail was suggested as was the ability to only view certain types of information at a time e.g. groups of fields having a common spray.

The types of information it was commonly believed should be on view or made viewable were:
- Hedges.
- Ditches.
- Buildings.
- Contours.
Streams.
Field notes - enlarge individual fields to identify weed areas.
Area (ha).
Crop (Split cropping should be allowed for).
A scale.
North.

Items which need recording but are not necessarily displayed are:
- Historical detail of fields.
- Cropping.
- Field name/ no. IACS ref.
- Notorial grid square number.
- Field area.
- Area of each crop.
- Total cropping area.
- Variety.
- Seed rate.
- Sowing date.
- Harvest date.
- Chemical & fertiliser application (organic and spray).
- Soil type.
- Weather.
- Cultivation.

The ability to compare information across time e.g. several years rotations, several years yields was requested by many of the groups. The ability to group information was also seen as very important to support decision making e.g. to see all fields growing a certain crop, or all fields requiring a certain treatment. One of the Dalgety group suggested a spreadsheet like view showing the related information. Clicking on options would allow the user to view different types of related information and to sort geographically.

Customisation
All participants would like the ability to customise the map in various ways, e.g. splitting fields, mapping of problem areas (pests, diseases, nutrition, ditches, wet holes, pH and acid patches), make changes to field boundaries etc., write on buildings, footpaths, boundaries and other special features. ADAS would find this type of customised map very useful as a means of passing information on to other advisers taking over the work for whatever reason.

Data handling
One particular concern of the farmer groups was the origin of the data used within the display. They were anxious that the information be pulled from their existing database (often Optimix) and that any changes should be propagated through the system. This was supported by the Dalgety group who stressed the need to pull in information from their existing Lotus spreadsheets. The degree of emphasis that was placed on this in spite of our explanations suggests that the data sharing concept has to be clarified and reiterated throughout the projects lifespan.
Defaults
Farmers wanted the current or previous values from their databases to be used as defaults, for field name, number, crop, variety. ADAS were also keen on the use of default values, e.g. last spray and date, last fertiliser and date and the ability to set default values. One farmer wanted to use field numbers as well as names as they are easier to enter quickly. The idea that the screen automatically opens in its last state was suggested by one farm group. In general the farmers wanted the same type of operations and command labels they had become familiar with in Optimix.

4.4.5 Additional information
- OS map level detail (ADAS, farmers).
- More detailed information on spray schemes and links to all information on sprays (farmers).

4.4.6 Additional facilities
The following suggestions were made by the groups for additional functionality:
- Yield/weed mapping facility (ADAS).
- PH/soil type/nutrient mapping facility with dates analysis carried out (ADAS).
- History of any repetitive problems (ADAS).
- Ability to scroll through all farms, fields and years to check, enter information (ADAS).
- Ability to show part farms, e.g. 1 farmer with 3 farms (ADAS).
- Ability to run on a laptop and transfer to office records (ADAS).
- Ability to indicate split field, mixed crops (farmers, Dalgety).
- Identification of parts of field with changing weeds/soil type/changing aspect and altitude (farmers, Dalgety).
- Zoom on parts of map (farmers).
- Ability to overlay maps (farmers).
- Rotation planning tool (farmers).
- List date of treatment with sprays so that checks on effectiveness can be made with regards fencing etc. (farmers).
- Easy access to crop history (farmers).
- To be able to fit in with GMS systems and historical yield maps (farmers).
- Ability to split the screen to view two years rotation (farmers).
- Ability to show a single field with tables etc. so can compare across years (farmers).
- Ability to access other software from within mapping system (farmers).
- Ability to pull information in from all sources and collate in standard forms e.g. IACS (farmers, Dalgety).
- Ability to take spray records in notebook form and download to this system (Dalgety).
- Colour printing (Dalgety).
- Ability to group fields by common treatments (Dalgety).
- Ability to enlarge an individual field (Dalgety).
4.5 Encyclopaedic data

4.5.1 General
None of the workshop participants had any difficulties with the hyper-link interface although the majority had not previously used one. They generally had a clear idea about what to do next although the organisation of the material did cause some irritation.

Most participants felt that the encyclopaedia would be useful to them. Speed of access, potential for keeping up to date, and compactness were seen as the main advantages of this type of system. The updating factor was seen as particularly valuable by all groups although the farmers and advisers differed slightly in their needs. Farmers were most interested in market and legislative information, advisers in research and chemical information. Compactness was of particular importance to both of the adviser groups, who it seems, currently carry a great many books around in their cars. The Dalgety group were concerned to stress however that unless DESSAC replaced all of their current information sources they would have nothing to gain from using it. This group felt that the time it took to start up a computer may well prove to give books the edge in the field.

Factors that were considered to be disadvantages were largely concerned with the encyclopaedias computer base. The following disadvantages were suggested:

- The need to keep a laptop with them (advisers)
- Inconvenient and not as useful as a piece of paper.
- A convenient printing facility would be required.
- Computers are bad for the eyes.
- Need to learn to use equipment.
- Power cuts.
- Memory/processor requirements.
  (ADAS and Dalgety are currently using fairly old, slow machines which am not be capable of running this software.)
- Fear of being hacked into if the machine is left on and connected to the Internet (Farmers).

There was also a lack of confidence in the accuracy of the information.

4.5.2 Navigation
All groups felt the information would be easier to access if the format was improved. One suggestion, which all groups approved, was the use of simple headings at each level. These would allow users to navigate their way swiftly to the relevant topic without having to scroll through pages and pages of material. The groups had slightly different ideas about the choice of initial topic i.e. crop name (ADAS, Dalgety); disease diagnosis (farmer); disease name (Dalgety). One of the Dalgety team suggested that varietal risk should be given at the top level so that the client could immediately see a summary table of resistance rating. Farmers wanted to go straight from identification of the disease to a table of disease against chemical effectiveness. The Dalgety group wanted to be able to access chemicals by either their chemical or trade name, and to have the active ingredients and variety effects highlighted.
The provision of 'go back to start' and/or 'go to next level up' options at the bottom of the page was suggested by one of the ADAS groups as a means to improve navigation.

**Search**
One of the farmer groups and one of the Dalgety groups used the 'Find' option and both were dismayed to learn that it only searched within the current page. Both groups wanted access to a full library type search facility which operates throughout the encyclopaedia. The Dalgety group wanted this facility to list all the items that matched the search description in a similar fashion to the BIDS database with which they were all familiar.

4.5.3 Display
Problems with the display characteristics were only raised by one of the Dalgety groups. This group was not happy with the contrast on the display, commenting that the blue and grey colours merged together. They also thought that the text size was too small.

4.5.4 Content

**Text**
Most participants thought that if the structure was improved, the material was pitched at about the right level. It was however felt to be a bit wordy. The presence of too much text was felt to be off-putting by the ADAS and Dalgety groups. Most groups suggested that the text could be reduced or replaced by pictures and diagrams. One felt that the detail would be easier to read as hard copy. The need for a glossary was mentioned by a couple of users.

**Pictures**
The pictures were admired by all groups but considered, particularly by ADAS, to be too clean and too small to be of much use in identification. Farmers also felt that they were too small for diagnostic purposes and that 10x, 25x, 100x magnification options should be available. The Dalgety groups also felt that the detail was too poor for diagnostic purposes. Good field based pictures at a variety of magnifications and possibly video footage would be more useful.

**Page length**
Most groups commented on the length of the pages. Small pages with options were seen as better than long pages and one Dalgety group suggested that information should be hidden unless specifically requested. One of the Dalgety groups suggested that there wouldn't be time to read all the basic information and that what they really needed was fast access to the latest recommendations and advice. An ADAS group suggested that they would like to be able to get at the information from different directions e.g. from disease, from crop or from chemical name.

4.5.5 Additional information
- **Drawings of disease and pest lifecycles**
  Additional drawings of disease and pest lifecycles, etc. were suggested by one of the ADAS and one of the Dalgety groups. The Dalgety group wanted the
lifecycle map to have a 'you are here' pointer and to link into symptoms and treatments for the different life cycle periods.

- Access to up to date information
  The type of information that both groups of advisers wanted access to was: disease lifecycle, disease control, crop response, dose response curves, product information, dose rates related to disease levels, and prices, all frequently updated. One of the farmer groups said that access to the latest information on legislation that affects them would be very useful, e.g. IACS, spraying near watercourses, etc. They often need a source of reference when filling in forms. Information they normally get from Farmers Weekly and market information would be particularly useful as would up-to-date trials information. Farmers were particularly interested in the latest Green Book information; updates from the Pesticides register; all chemical information and associated COSHH regulations. More generally farmers wanted information on growth stages, disease identification, fungicides, cultivation techniques, nutrition effects, chemicals, tank mixes, and safety.

- Testing and how to do it (farmers)
- Good field based pictures at a variety of magnifications, e.g. 10x, 25x, 100x, and possibly video footage.

4.5.6 Additional facilities
A number of additional facilities were suggested by the participants, these were:

- Support in disease assessment
  For example pictures of disease at different percentage levels, was suggested by all groups but particularly by ADAS and Dalgety. While ADAS seemed to feel the information should be stored in the encyclopaedia, one of the Dalgety groups felt that it belonged with the fungicide decision support module.

- Ability to collate information and print on standard forms
  Having identified the relevant chemical information farmers (or advisers) would need to be able to print it out on a standard spray sheet. The ability to access information from across the DESSAC system and input it into standard forms e.g. Spray sheets, IACS returns, etc. was seen by farmers as being extremely useful.

- Propagation and storage of new information
  Storage of spray records and other related information in a conveniently accessible form would be useful to farmers, for sending to the HSE on request. Farmers were at pains to point out that information found or created whilst using DESSAC should be capable of being stored back in their current data systems e.g. Optimix, Health and Safety records, etc.

- Facilities for linking into Psions or other notebooks
  One of the farmer groups and one of the Dalgety groups raised the issue of portability. Both felt that data entry while in the field was necessary and that carrying a PC around was somewhat impractical. To avoid the need to re-
enter data they suggested that the system should be able to import information from electronic notebooks e.g. Psions.

- Link into information from diagnostic kits in field.
- Help on weed identification at different points of the life-cycle (farmers).
- Full search facilities (e.g. keyword, author, Boolean operators) that cover the whole encyclopaedia, not just single pages.
- Copy and print facilities.
- Help on assessment.
  To see pictures of different levels of disease, perhaps as a training tool.
- Ability to scan a leaf to see its leaf area index.
- Updates to be flagged and accessible from the top level.
- An automatic link from a met data warning to the information on specific diseases.
- Ability to look at two things at once e.g. Yellow rust on Wheat and Barley.
- Approximately half of the ADAS and farmer participants would like to be able to customise the information by adding their own notes.
## 5.0 WORKSHOP QUESTIONNAIRE RESULTS

The results of the questionnaire administered to participants at the end of the workshop are listed below in the order of their presentation.

### 5.1 How would you rate the organisation of the workshop?

<table>
<thead>
<tr>
<th>Rating</th>
<th>Advisors</th>
<th>Farmers</th>
<th>Dalgety</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>V. Good</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Good</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Poor</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>V. Poor</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>17</td>
</tr>
</tbody>
</table>

The participants seemed to feel that the workshop was well organised. The advisers give the highest ratings which may reflect the fact that there was less discussion, and we managed to keep reasonably closely to time, in their session.

### 5.2 Do you feel you’ve been given enough information on the DESSAC project?

<table>
<thead>
<tr>
<th>Rating</th>
<th>Advisors</th>
<th>Farmers</th>
<th>Dalgety</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>No</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>17</td>
</tr>
</tbody>
</table>

Comments: Early stages yet - See again next year? For the moment. A bit rushed.

All participants seemed to feel they had been given enough information on the DESSAC project for the time being.

### 5.3 Do you think you’ve been able to comment fully on the DESSAC software you’ve seen today?

<table>
<thead>
<tr>
<th>Rating</th>
<th>Advisors</th>
<th>Farmers</th>
<th>Dalgety</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>No</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>17</td>
</tr>
</tbody>
</table>

Comments: Need more time to study questions and flick through pages Further development Another opportunity in a years time
5.4 How do you feel about the DESSAC system based on experiences in this workshop?

<table>
<thead>
<tr>
<th>Rating</th>
<th>Advisors</th>
<th>Farmers</th>
<th>Dalgety</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>V. Positive</td>
<td>3</td>
<td>2</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Positive</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Negative</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>V. Negative</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>17</td>
</tr>
</tbody>
</table>

Comments: All right if modules can be interlinked together

Farmers and advisers left the workshop feeling positive about the DESSAC system but the Dalgety group were less enthusiastic. This may have been due to the rushed nature of the event as well as the more cynical view the agrochemical industry has about the things we're trying to achieve. Three positive responses may therefore be fairly encouraging!

5.5 Do you think you would use the DESSAC system when it is completed

<table>
<thead>
<tr>
<th>Rating</th>
<th>Advisors</th>
<th>Farmers</th>
<th>Dalgety</th>
<th>Total</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>Time, Price? Up to dateness. Depend on cost. See it nearer the final product. Depends on level of link up to Optimix etc. and other developments and applicability to individual.</td>
</tr>
<tr>
<td>Maybe</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>But this is because it is not my job to</td>
</tr>
<tr>
<td>No</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

The adviser group gave the most positive responses to this question, the farmers were less sure. The Dalgety groups responses were again surprisingly positive. The only negative response came from one of the Dalgety group who wasn't a potential user. The six 'maybe' responses indicate that DESSAC has to continue selling the ideas to farmers and the agrochemical industry.

5.6 What do you think would be a reasonable price for the DESSAC system with winter wheat fungicide module

<table>
<thead>
<tr>
<th>Rating</th>
<th>Advisors</th>
<th>Farmers</th>
<th>Dalgety</th>
<th>Total</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than £500</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>It is probably too early to comment. It does depend a lot on the completed system.</td>
</tr>
<tr>
<td>£500 - £1000</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>£1000- £1500</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>£1500+</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>No answer</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>Too soon to tell yet</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>
The highest values placed on DESSAC and the WWF module were by the ADAS group. The farmers and Dalgety group generally went for the lowest cost headings. In discussions farmers and chemical representatives were far more interested in budgets and costs than the ADAS group. Both groups seem to be aware of tight margins and of the need to ensure that purchases are cost effective.

5.7 Any other comments

<table>
<thead>
<tr>
<th>ADAS</th>
<th>Essential to keep workshops going to monitor progress on program. (Advisor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dalgety</td>
<td>Not about the workshop, but the effects this will have within the industry need careful consideration. Its perceived use, threat or benefit to those involved.</td>
</tr>
<tr>
<td>Dalgety</td>
<td>I think there is a need to collate information from various sources and so summarise findings. The major difficulty is when to use the system and/or where, i.e. whether on our lap tops or in the farm office. I don't think that the system will be used a lot when farmers and their advisers are very busy in April, May and June.</td>
</tr>
</tbody>
</table>
6.0 CONCLUSIONS AND LESSONS LEARNED

The workshops proved to be a useful and productive method of fulfilling project objectives. The participants seemed to feel that the workshops were worthwhile and much positive feedback was received. They appeared to be confident that their comments had been noted, and would be acted upon, and left with a generally positive view of the DESSAC project. The User Needs Working Group were able to refine and extend the scope of the user requirements and the Technical Working Group were able to get first hand experience of the user feedback, including many suggestions for improvements and refinement.

With regard to the emerging DESSAC system all participants seemed to like the idea although the systems eventual existence and robustness were treated with varying degrees of scepticism. The farmers felt that the main concept behind DESSAC i.e. bringing all the information together, was 'incredible'.

The results documented within this report have since been discussed by the various working groups within the project and incorporated into future planning. In particular the comments on the user requirements summary and the feedback from the demonstration sessions have been used to produce a new version of the statement of user requirements (UNG 6.0).

Although the workshops were generally successful there were a number of areas where improvement could and should be made when the exercise is carried out again.

The pre-workshop task
Participants in the user workshops were asked to complete a task prior to the workshop, the aim of which was to focus attention on the issues to be raised. However, as the task was not completed by any of the participants in this round, its use to future workshops is debatable.

Validation of user requirements
The first group asked to comment on the user requirements did so individually, and there was a definite 'examination' feeling during the period they were engaged in the activity. For subsequent sessions, the workshop participants were therefore asked to complete this task in pairs. This proved more successful, in that there was less pressure on individuals and pairs had the opportunity to discuss what they were doing. It is recommended therefore that pairs be used during any future validation exercise.

Time available for the user workshops
The major problem encountered during the workshops was lack of time. Three hours was simply insufficient to present and collate the quantity of information required. The situation was exacerbated by Dalgety's decision to reduce the time available to the project to 1.5 hours to make way for a management meeting. Dalgety were therefore unable to comment on the user requirements.
As well as reducing the potential for data collection, there were a few comments from participants feeling rushed. On this basis the recommendation for future workshops is that a 'short' day should be set aside for each event, e.g. 10am - 4pm, and that on no account should the session be seen as part of another meeting. The need for additional time will become particularly important later on in the project when the system increases in complexity and more detailed feedback is required.
APPENDIX G:
DESSAC User requirements specification document


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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1.0 Introduction

This document contains the summarised results of surveys carried out by the User Needs Group between Oct. 1994 and Sept. 1996. It is intended to serve primarily as a statement of the users requirements for the DESSAC winter wheat fungicide module (WWFung). That is, a statement of the things the module will have to provide in order to fulfil the needs of those farmers and advisers who currently take decisions about winter wheat fungicide applications. The document is designed to be used as a reference work and as such contains a degree of repetition as information is presented in different ways to suit a number of different purposes.

The aim of the winter wheat fungicide module within the DESSAC framework is to provide those people who currently make fungicide decisions with sufficient information to permit them to make more cost-effective and timely spray applications. Use of the decision support tool should move the average level of decision making closer to the optimum.

The first phase in any decision making process is the search for problems that need to be resolved (Simon, 1977): while this is a continuous process in any business, a number of key problems occur regularly and can be predicted. The identification of these reoccurring problems is the basis for the design of a support system i.e. once the problems are defined it is possible to specify the means by which the next phase 'inventing, developing and analysing' (op cit.) possible courses of action can be supported.

If problems are defined by the questions a user asks, or is asked, in connection with the use of winter wheat fungicides then it becomes easier to identify the data required to support the decision. If an 'expert' decision maker is asked a question e.g. 'Should I spray for x now' they will request and reference additional data and process it, possibly using 'rules of thumb', to produce an answer. These processes are observable and, to a certain extent, open to introspection. The process of eliciting the data the decision support tool needs to provide is therefore easier when the questions have been defined.

Identifying the questions users ask when making fungicide decisions has another benefit, it provides the system developers with a useful set of evaluation criteria: if the software cannot answer the questions the users need to ask of it, then it will not provide the support they need. The current understanding of the questions the makers of fungicide decisions will want to ask of WWFung, and the information that is required to answer them, are summarised in Sections 1 and 2 of this report.

Having identified the information the user needs to access, it is useful to categorise it according to its potential source as this may influence the design solutions chosen. Four categories seem appropriate in this context: (A) information from the user, either input directly or accessed from previous inputs; information provided by external sources which is either (B) static i.e. does not need to be updated more than once or twice a year or (C) dynamic i.e. is constantly changing; and (D) information produced by the manipulation of data from any of these sources. Examples of such information might be: (A) drilling date; (B) product safety recommendations; (C) weather forecast; and (D) margin over spray cost. Section 3 presents the information required to answer fungicide
questions within these categories, together with more general requirements. Each category of information places a different emphasis on the design requirements: ensuring that the user will be able to input and store information; ensuring the collation, delivery and updating mechanisms for external information; and building the models and facilities required to manipulate the data.

The four categories discussed above are represented as items A-D in the diagram below (Figure 1) which illustrates the flow of information around the winter wheat fungicide module. The diagram shows the information being presented to the user through the user interface. The design itself is described in detail in (Beaulah, 1996). An additional section will be included in future versions which explains the process of incorporating user requirements into the interface design. This section will also contain a clear statement of the degree to which the system should be offering 'advice' i.e. interpreted information, as opposed to pure data: a question which is still being actively debated within the project.

![Diagram of information flow in the DESSAC winter wheat fungicide (WWFung) system](image)

Figure 1: Showing information flow in the DESSAC winter wheat fungicide (WWFung) system

While it is recognised that computer technology is moving too fast to speculate on the future shape of the hardware, as represented by area (F) in figure 1, some basic requirements for the system were identified during the user surveys and are presented in Section 6.0

Area (G) of the diagram represents the wider context in which the winter wheat module must operate and the current state of knowledge on these other factors is presented in Section 5.0 In addition to forming a background for the WWFung design, this section may be used as a source of material for identifying other potentially useful modules.

Section 4.0 contains a set of scenarios in which the use of the winter wheat module is set in realistic task based contexts. Each scenario describes the use of the system by farmers
or advisers at different points of the year. The scenarios will be employed to explain the potential of the system to external bodies and used as the basis of demonstrations and workshop sessions.

Section 7.0 of the report contains a description of the evaluation criteria which are partially derived from the user requirements analysis and which will be used to judge the usability of the WWFung module throughout its development as an addition to the yearly user workshops.

The final section of the report, Section 8.0, is the WWFung 'style guide'. A style guide, or statement of features to be standardised within the software, is required by the project in order to reduce ambiguity and increase usability. This guide, currently in embryo form, will be updated on a regular basis. The current styles have been agreed by the user working group.
2.0 Questions to be answered

The first phase in any decision making process is the search for problems that need to be resolved (Simon, op cit.), the identification of these reoccurring problems is the basis for the design of a support system i.e. once the problems are defined it is possible to specify the means by which possible courses of action can be supported. Within the scope of this project users questions within the winter wheat decision making process have been defined as the 'problems' the WWF system has to support.

When making decisions about any activity it is necessary to ask questions. These may be questions to oneself e.g. what do I want to achieve, or of external agencies e.g. what will this cost. If questions which are regularly posed in relation to a decision can be identified then it becomes possible to identify the means by which answers can be provided and the question posing process supported. Knowing the important questions permits the identification of the source of information required to answer them and the additional tools needed to manipulate and convert the information into something meaningful. In short, identifying the critical questions permits the shape of the decision support tool to be specified.

Winter wheat fungicide questions were elicited from users during the user surveys and user workshop sessions. These are presented in the appendices in order of their appearance during the season and also in order of their perceived importance as determined by advisers within the user working group.

The questions in their raw form do not provide a clear view of the requirements for the decision support tool and a means of translating them into something more concise was sought. A process of sorting them into associated groupings led to a form which mapped almost precisely onto a taxonomy described by Arinze in a 1989 paper.

Arinze refers to questions as 'decision enquiries' or DE's and believes their identification is essential in decision support tool development. He proposed 3 levels of decision enquiry: 'state' enquiries (what is/what might be the current state); action enquiries (what should I do to achieve x); and projection enquiries (what will happen if I do y). The identification of state enquiries permits the definition of the information requirements of a decision support system, identification of the action and projection enquiries defines the design of the system itself (functionality and interface requirements).

The questions identified within DESSAC can be summarised and presented within the taxonomy in the following form. These are the top level, generic questions which the decision support system will have to be able to answer to be of use to the farmer making winter wheat fungicide decisions.
Is there something about which I need to take action?

- Have I/is there possibly going to be a problem?
- What is it/might it be?
- How serious is it/might it be?

**STATE**

Description of current state

- Risk strategy
- Extent/potential for development of problem
- Value of crop

**What do I do?**

- What chemicals will do the job?
- Which are best for me?
- What is the best way to use it/them? (dose/timing)

**ACTION**

Tell me how to get to x - optimum position

- Availability
- Tank mix
- Related activities

**What if?**

Changes to options
Changes of weather
Changes in disease levels

**PROJECTION**

Tell me what will happen if y changes

The actual questions which users posed, and the information needed to answer them, are presented below under each of these top level headings:
### 2.1 STATE DECISION ENQUIRY

**Key question:** Is there something about which I need to take action? (Problem definition)

#### Examples from user requirements exercise:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
</table>
| 1-2  | Do I need to apply fungicide? | Disease presence - 'easily found'
|      |          | Trials data
|      |          | Local Information and geographical risk |
| 1-2  | Do I need to spray 'against eyespot'? | It is present?
|      |          | Growth Stage
|      |          | Crop health/condition
|      |          | Is anything else being treated (going through anyway)
|      |          | Action at 30/31 (previous action)
|      |          | Previous cropping
|      |          | Level in field
|      |          | Drilling date |
| 1-2  | Do I need to spray for septoria, yellow rust, or mildew? | Disease presence (easily found and spreading for Mildew and easily found for Rust)
|      |          | Growth stage, leaf emergence
|      |          | Trials results
|      |          | variety risk rating
|      |          | Current and recent past weather conditions - particularly rainfall
|      |          | Past weather conditions
|      |          | Past crop info (spray, sheet comments)
|      |          | Action at 30/31, Drilling date
|      |          | Mean of last 3 years |
| 1-2  | Should I spray to control diseases of the ear? | Growth Stage
|      |          | Variety
|      |          | Weather |
| 1-2  | Should I add a morpholine to the main fungicide? | Disease presence |
| 1-2  | Do I need to use a protectant as well? | Target leaves emerged at time of spray? |
| 2    | Should I apply an ear-spray? | Disease presence |
| 2    | When will leaf 3 emerge? i.e. do I need to spray against septoria? | Date of drilling.
|      |          | Temp on April & May
|      |          | (Growth stage model ideally) |
| 2    | Should I treat the seed? | Is it home saved or certified |

**Sub question:** Have I (could I possibly have) a problem?

#### Examples from user requirements exercise:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
</table>
| 1    | Is there septoria in the crop? | Inspection
|      |          | Weather
|      |          | Is leaf 3 emerging? |
| 1-2  | Has rainfall incident occurred? | Recent past weather |
| 2    | Is this variety susceptible to this disease? | NIAB
|      | or What is the risk posed by disease | Local Trials
|      |                                    | Geographic risk |
| 2    | What diseases are my varieties susceptible to? | NIAB ratings, local trials, local risks |
### What is it?

**Examples from user requirements exercise:**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>What is this disease?</td>
<td>Photos, descriptions</td>
</tr>
</tbody>
</table>

### How serious is it (might it be)? - how great is risk

**Examples from user requirements exercise:**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>What impact will this decision have on my margin over spray cost?</td>
<td>Margin over spray model</td>
</tr>
<tr>
<td>1-2</td>
<td>What are the financial implications of this decision?</td>
<td>Cost of spray</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Margin over spray cost</td>
</tr>
<tr>
<td>1-2</td>
<td>What is the likely loss if I do nothing?</td>
<td>Yield records for indiv.fields, varieties</td>
</tr>
<tr>
<td>2</td>
<td>How long till flag leaf fully emerged</td>
<td>Growth model</td>
</tr>
<tr>
<td></td>
<td>What are chances of disease spread in that time</td>
<td>How long has leaf 2+3 been out</td>
</tr>
<tr>
<td>3-4</td>
<td>How do I estimate the extent of this disease?</td>
<td>Keys, DISTRAIN</td>
</tr>
<tr>
<td></td>
<td>How will risk develop</td>
<td></td>
</tr>
</tbody>
</table>
### 2.2 ACTION DECISION ENQUIRY

Key question: What do I do? (to solve problem)

Examples from user requirements exercise:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What is the best strategy for this field/variety?</td>
<td>Trials data especially local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Market information</td>
</tr>
<tr>
<td>2</td>
<td>What future steps do I take to avoid disease?&lt;&lt;optimise&gt;&gt;</td>
<td>Examples of typical spray programmes</td>
</tr>
</tbody>
</table>

Sub question: What will do the job?

Examples from user requirements exercise:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>What treatment should I use out of the (possibly 6) available?</td>
<td>Cost, availability of products</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Users judgement of risks (risk last year, test results,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>weather after harvest)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drilling date</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Area risk rating (mostly yellow rust)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variety risk rating for list of diseases</td>
</tr>
<tr>
<td>1-2</td>
<td>Which product/active could I use for this problem?</td>
<td>Availability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Green book (not complete)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pesticide register</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost (use price bands, or pick up from previous year or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pick up from user entered information)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity level of active/product (trials)</td>
</tr>
<tr>
<td>2</td>
<td>What fungicides should I buy for the season?</td>
<td>Availability, price</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variety, area of country</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diseases present (for in season decision)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dose response curves</td>
</tr>
<tr>
<td>2</td>
<td>Does the recent past/current weather affect the present decision?</td>
<td>Label, pesticide register, pesticide manual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>for effect of weather on performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Models showing effect of weather on disease development</td>
</tr>
<tr>
<td>1-2</td>
<td>Which of the available chemicals is the best for the job?</td>
<td>Grouping of product in efficacy terms</td>
</tr>
</tbody>
</table>
### Sub question: Which is the best for me?

#### Examples from user requirements exercise:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How does spray A compare to spray B?</td>
<td>Dose response curves, Cost</td>
</tr>
<tr>
<td>1-2</td>
<td>Which of these chemicals is the most effective?</td>
<td>Cost of chemical, Tank mix Cost of time changes - need for increased dose if spray later Potential yield loss from not spraying now The lowest dose for effective control, taking into account: Time, GS, Variety, Yield potential - market and market value, Disease pressure (Sowing date, Crop canopy structure, Weather (pre), Weather (post), Soil factors (type))</td>
</tr>
<tr>
<td>2-3</td>
<td>Duration of effect (eradicant and protectant) of chemical?</td>
<td>Needs to be researched from trials data</td>
</tr>
<tr>
<td>2/4</td>
<td>What should I use to reduce resistance of fungal disease to the chemical?</td>
<td>Variety, dose response curves</td>
</tr>
<tr>
<td>3</td>
<td>Why is that chemical best for this problem?</td>
<td>General information on chemical and disease</td>
</tr>
</tbody>
</table>

#### Tank Mix issues

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Will these chemicals mix? e.g. Opus with Cheetah? If they don't mix what should I do? What alternatives are there? What is definitely excluded in tank mixes Because illegal Because will kill/damage crop Chemicals physically incompatible i.e., solidify when mixed</td>
<td>Pesticide manual Green book, pesticide register Label information Own notes Manufacturers technical manuals Farmers weekly (need for a specific module to answer this question - info not currently available in easy to access form)</td>
</tr>
<tr>
<td>1-2</td>
<td>Are there any specific restrictions with this chemical e.g. not spray near a watercourse?</td>
<td>Pesticide manual Green book, labels and pesticide register</td>
</tr>
<tr>
<td>2</td>
<td>Is seed treatment compatible with insecticide?</td>
<td>Label information</td>
</tr>
</tbody>
</table>

#### Availability issues

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Is this chemical available from my stockist?</td>
<td>Supplier information</td>
</tr>
</tbody>
</table>

#### Other practical considerations

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>What impact will the tank residue have on my next crop?</td>
<td>Pesticide manual Green book, pesticide register Label information</td>
</tr>
<tr>
<td>2</td>
<td>What other crops can this chemical be used on?</td>
<td>Pesticide manual Green book, labels and pesticide register</td>
</tr>
<tr>
<td>2</td>
<td>What are the safety considerations with this choice?</td>
<td>Pesticide manual Green book, labels and pesticide register</td>
</tr>
<tr>
<td>2</td>
<td>What is the window of opportunity for spraying as of now (today)?</td>
<td>User records of machine availability etc Weather forecasts</td>
</tr>
</tbody>
</table>
Examples from user requirements exercise:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What is the most effective dose for my purpose?</td>
<td>Dose response curves</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Date of application</td>
</tr>
<tr>
<td>2</td>
<td>If I leave spray for 'X' days which is the best chemical/dose then?</td>
<td>Chemicals listed in eradicant activity order</td>
</tr>
<tr>
<td>1-2</td>
<td>What impact will the current weather conditions have on my spray choice, decision e.g. should I put on more, or less or wait?</td>
<td>Label, Pesticide register Eradicant activity of chemicals</td>
</tr>
<tr>
<td>2</td>
<td>When was the last spray date and what did I use?</td>
<td>User records</td>
</tr>
</tbody>
</table>

### 2.3 PROJECTION DECISION ENQUIRY

Key question: What will happen if?

Examples from user requirements exercise:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Can I delay my 'flag-leaf' spray until GS59?</td>
<td>Disease in Crop</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recent weather conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variety</td>
</tr>
<tr>
<td></td>
<td>What will happen if I change any of the options e.g. chemical choice/dose etc</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What will happen if weather does X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What will happen if disease pressure does Y</td>
<td></td>
</tr>
</tbody>
</table>

### 2.4 GLOBAL INFORMATION REQUIREMENTS

The process also highlighted the global requirement for access to information about current growth stage and for access to the source of information used in the system.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>What is growth stage of the crop?</td>
<td>Drilling Date</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weather</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User input (with checks)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Photos/diagrams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Restrictions on chemical</td>
</tr>
<tr>
<td>2</td>
<td>Where did this information come from?</td>
<td>Publication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Date</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Abstract of source</td>
</tr>
</tbody>
</table>
3.0 Requirements by information type

3.1 Information flow
The questions in Section 2 identified a wide range of information types which the user will need to access within the winter wheat module if it is to support them in making decisions. In its current form it is not possible to see what impact the information requirements will have on design. An early discussion of the data suggested a method of categorising the data to make it useful to the systems designer, that is to categorise each piece of information according to its source. Four categories were deemed to be appropriate and are illustrated in figure ** below (A) information from the user, either input directly or accessed from previously inputs; information provided by external sources which is either (B) static i.e. does not need to be updated more than once or twice a year or (C) dynamic i.e. is constantly changing; and (D) information produced by the manipulation of data from any of these sources. These four categories are used in this section as a means of meaningfully organising the information requirements. Other decisions (G) and physical requirements (F) are discussed in sections 5 and 6 respectively.

![Diagram showing information flow in the DESSAC winter wheat fungicide (WWFung) system](image)

**Figure 2: Showing information flow in the DESSAC winter wheat fungicide (WWFung) system**

Information categories
Each category of information places a different emphasis on the design requirements e.g. ensuring that the user will be able to input and store information; ensuring there are collation, delivery and updating mechanisms for external information; and building the models and facilities required to manipulate the data.

Information requirements are presented below under each of the category headings. Where appropriate general requirements and the justification associated with the category are also listed.
3.2 Direct input from the user

General Requirements:

3.2.1 Wherever possible default values must be provided.
Users may not have immediate access to real values (e.g. growth stage) but still want to continue with the activity using approximations.

3.2.2 The system should reduce the number of user inputs to a minimum.
Users will become frustrated by a system which demands many inputs. This also means that there must be an effective method of producing default values.

3.2.3 The range and format of expected values must be available to the user.
Users will become frustrated if they have to 'guess' the range and format of inputs.

3.2.4 The system should prevent users from entering invalid data.
If invalid data is entered, invalid results will be produced and users will lose confidence in the system.

3.2.5 Users must be able to select the input measure with which they are familiar e.g. acres rather than hectares, week number rather than calendar date. Users will find it irritating and/or difficult to have to convert from familiar measures.

3.2.6 Information requirements
The key information that users may wish to store and which will be required by the winter wheat decision support software is:

Records

Field based records
(information on past years and on 'below ground level' aspects of the field)
- Identification (name, IACS No.)*
- Size*
- Soil type
- Soil nutrient status (Own test results)
- Cropping history (yield records by field and variety)
- Action at 30/31
- Date of application

Crop based records
(information on current years crop and 'above ground' data)
- Current varieties
- Is it home saved or certified seed
- Dates drilled (likely date of drilling)
- Dates emerged
- Dates harvested
- Spray records (notes, inspection sheet, tank mix)
- Yield potential*
- Actual yield*

*indicates essential information which was not directly elicited from questions
Observations
- Crop canopy structure
- Crop health/condition
- Disease presence
- Disease level
- Leaf emergence,
- Growth stage (or from model)
- Cost of chemicals

Other, potentially user based, information
- Cost of chemicals- previous year
- Weather - current and past weather conditions - particularly rainfall
- Date e.g. week 15, GS 31/32
- Area risk rating
- Area of country
- Availability of products
- Disease pressure
- Is anything else being treated at the same time
- Users judgement of risks
- Notes - on decisions, fields, varieties*

Non essential information requirements
This is information which has been suggested by users as potentially useful, but not essential within the context of the winter wheat fungicide module:
- Records of machine availability etc
- Cultivation history
- Altitude
- Location (aspect)
- Rotation
- Drainage maps
- Yield maps
- Market
- Storage & drying capability
- Fertiliser records
- Cultivation

*indicates essential information which was not directly elicited from questions
3.3 Information from external sources (static)

This is information sourced externally (i.e. not input by the user) but which is fairly static and requires infrequent updating and could therefore be supplied to the user on CD or disc.

General Requirements:

B.1 Information relevant to the DESSAC winter wheat fungicide program from DESSAC compatible internal sources should be immediately accessible to that program, without any recovery actions on the part of the user. The use of information by DESSAC modules should be 'seamless' as far as the user is concerned.

B.2 Existing data from pre-DESSAC programs should also, where possible, be made accessible i.e. through the use of translation programs. Many users have invested considerable time in building up existing databases; they will be less willing to use DESSAC modules if that effort has to be repeated.

B.3 Where possible efforts should be made to develop information packages for several platforms e.g. hard disc storage and CD. Not all users will have access to CD drives.

B.4 The main types of external 'static' data users will need to access are:

- Pest and disease information (photos diagrams)
  - identification
  - life-cycle *
  - predicted development under certain weather conditions.
  - threat to crop *
- Variety ratings e.g. NIAB
- Weather - current and past
- Agrochemical information
  - composition
  - action
  - eradicant activity
  - activity level of active/product
  - persistence (duration of effect, eradicant and protectant)
  - safety requirements
    (from Labels, Green Book, Pesticide manuals, Manufacturers technical manuals, Pesticide register)
- Farmers Weekly or other source tank mix compatibility information
- Area risk rating
- Trials data (inc. local trials data)
- Varietal susceptibility
- Cost of chemicals- price bands
- Papers including abstract & full details of source? *

Would also be useful, but not essential, to users:

- Pesticide/fungicide resistance
- Chemical company product database
- Chemical price database
- Business management information, e.g. as in the Nix handbook.

*indicates essential information which was not directly elicited from questions
Information from external sources (dynamic)

This is externally sourced (i.e. not from the user) information which requires continual updating to be useful. This type of information may be best provided via dynamic communication links such as the Internet.

General Requirements:
Most of these requirements relate to the DESSAC framework and not to the individual modules it will contain but they are included here for completeness.

C.1 DESSAC modules should be able to make use of information from:
- Weather stations
- Data recording devices
- Internet sources

The success of some future simulation models may depend on the accuracy of local weather data and facilities to access this data will therefore have to be provided. Access to the Internet will allow users to obtain more current data than that available via internal sources. It will permit service providers to market advice and information packages and to provide pricing details.

C.2 Users should be able to access this type of information in the same way that they access other data, but:
- users should be made aware that a call is required and that they will be charged, and
- users should be given some indication of the cost of the call they are making.

External calls have cost implications that users may not be aware of, while users do not need to know where the information is located they do need to be involved in the decision to spend money.

C.3 The technicalities of enabling external access should be included in the DESSAC 'set up' process.
Many users will be daunted by the prospect of setting up their own account with a network service provider. Ways should therefore be found of removing this task from the user and putting it in the hands of a service provider.

C.4 Access times should be fast. Where delays occur or large amounts of data are transmitted the user should be kept informed of progress and given the option to cancel the operation. If possible the user should be able to continue with other on-screen tasks while the transfer is completing.
Feedback is necessary for the user to schedule their activities. People are much happier if they know an operation will take a certain amount of time as it allows them to get on with other tasks.

C.5 Automatic down-loading of large amounts of data at off-peak times should be facilitated.
Time on-line is costly and user time is precious. An automatic facility will make the use of external data more acceptable to the user.

*indicates essential information which was not directly elicited from questions
C.6 The requirements for external (dynamic) information are:

- Market information
- Disease pressure (local disease pressure)
- Availability of chemicals
- Weather forecasts
- Pesticide updates
- Trials updates
  - Variety resistance ratings and changes to them

Would also be useful, but not essential, to users:

- Seed availability
- Collated research data
- Updates on research
- Local/regional warnings or advice
- Links to GIS systems
- Advice from own consultants
- Price information for chemicals, fertilisers, machinery, etc.
  (possibly a private link with supplier)

*indicates essential information which was not directly elicited from questions
D Manipulation of information by the DESSAC winter wheat fungicide module

General Requirements:

D.1 While most of the processing of information should be hidden from the user, the system should explain its activities during lengthy processing tasks. Information about the methods used by the program should also be made available through 'help' or 'information' facilities.

In general the user will not be interested in the inner workings of the system and will simply need feedback that the program is progressing and hasn't 'died' on them. However some users, most notably consultants, will want to know the basis on which decision support systems are making their recommendations. Such users will be suspicious of any 'black box' approach.

D.2 Where data has been called into a program, and its value is altered by the actions of the program or the user, the user should be consulted before the new value is propagated through the system or permanently saved.

The ability to manipulate data from a variety of sources is very useful as is the ability to carry out 'what if' manipulations, however, the user may not realise the effect changing a single piece of data will have on the rest of the system. Users will have to be protected against making unrecoverable, system wide changes to values.

D.3 User requirements for manipulation by DESSAC

- Ability to do 'what ifs' and show impact on yield and margin over cost with regard to input applications, changes in spray date, etc.
- Calculation of cost and effect on dose of delaying or bringing forward spray application
- Calculation of disease threat
- Calculation of effect of weather on disease development
- Calculation of current growth stage
- Ability to sort data e.g. trials data*
- Dose response graphing
- Optimisation - calculation of the lowest dose for effective control
- Calculation of yield potential - calculated from trials data
- Calculation of margin over spray cost
- Calculation of means e.g. of last 3 years (anything)
- Chemicals listed in eradicant activity order
- Grouping of products in efficacy terms
- Calculation of weather averages over past x years for use in forward planning

*indicates essential information which was not directly elicited from questions
4.0 Scenarios

The first part of this section contains a set of scenarios in which the use of the winter wheat module is set in realistic task based contexts. Each scenario describes the use of the system by farmers or advisers at different points of the year. The scenarios will be employed to explain the potential of the system to external bodies and used as the basis of demonstrations and workshop sessions. The second set describes the use of DESSAC in a slightly broader context.

4.1 Winter Wheat module

WWFung - Tactical decision

The farmer has just been checking out his fields of Brigadier and has seen there is a lot of mildew and septoria tritici in the crop. He is planning to spray the field with Opus and Bravo the following week which will be growth stage 39. His spray program is based upon the control of septoria tritici and yellow rust, but he thinks that the mildew will be a problem.

The farmer starts up the WWFUNG module in tactical mode and brings up the spray plan for one of his fields of Brigadier. He clicks on the 'Enter disease levels' button and enters the diseases he has seen in the field: because there is a lot of mildew he inputs the level of disease on the detailed observation screen instead of just indicating the presence or absence of each disease. Having entered the observations he returns to the tactical screen where the new information has been added. To see the effect of these observations he clicks on 'Run model' and the system indicates that he will lose yield and profit because of the increased mildew.

The system shows that the septoria is dealt with by the current spray plan but the mildew will continue unchecked. To discover what possible actions are available the farmer clicks on the 'Optimise' button. This indicates that a spray for mildew should be added to the tank mix and the suggested actions box shows that the best option is to add a Morpholine. The system shows that this option will give a better yield and financial return.

The farmer checks the tank mix by clicking the right mouse button over the future spray icon. The system shows the current tank mix with an additional Morpholine product in italics. The farmer wishes to check the performance of the new tank mix so he clicks the Fungicide Performance' button. A new screen is displayed showing graphs of margin over spray costs and percentage disease remaining against chemical dose. The graphs show the performance of the Bravo and Opus tank mix and a shaded area around the performance line show the variability which is possible with this action. He adds a morpholine product to the mix and new lines are added to the two graphs. It is clear that the second tank mix gives better disease control and a half dose gives a better financial return. The farmer decides the second tank mix is a good idea and agrees to it by clicking the 'Apply' button. He exits the fungicide performance and tank mix screens and saves the revised plan.
WWFung - Strategic decision
A consultant is helping the farmer plan the spray program for the coming season. It is February and they are developing a plan for the fields of Hunter. They start up the WWFung module and switch to strategic mode. The system displays the current spray plans for all the fields which shows when and at what growth stage each field and variety will be sprayed. They select a field growing Hunter from the map viewer and switch to single field view. The system displays the expected disease risks and critical action areas for Hunter along the time line.

The farmer and consultant decide to pull up a plan which was used on Hunter the previous year, which shows they sprayed at growth stage 31, 39 and 59. They click 'Apply' and the plan is overlaid onto the time line for the current year. They check the varietal disease ratings for Hunter and see it is very resistant to septoria tritici so they decide to see what effect removing the growth stage 31 spray has. They remove the 31 spray from the time line and click on 'Run model' to see the effect. The system shows that the yield is only marginally affected but because of removing the cost of the spray the return per hectare has increased by £25. They test out the durability of the new spray plan by changing the weather conditions and disease pressure. They see that plan is robust and save it. They return to the overview and the new plan for Hunter has been incorporated into the general plan and is displayed.

4.2 WWFung plus supporting material.

Full system - Strategic decision
It is early spring and a farmer is sitting down with his adviser to work out the spray plan for the season. This year they are trying out a new variety of winter wheat in one field in addition to the range of more familiar varieties (thus requiring access to more external information than usual). The new variety was recommended by the adviser based on their interpretation of recent trials results. The farm is located in a high risk septoria area and the new variety has proved fairly resistant.

The farmer and adviser sit down together in front of the computer in the farm office and the farmer brings up the strategic planning tool from the WWFUNG menu. To begin with they make sure that the planner contains all the information it needs, checking that the fields have the right varieties entered into them and adding or changing information as appropriate.

The adviser then asks the farmer to pull up last years spray plan and the notes that went with it. They look over the performance of each variety and discuss making changes.

As the farmer hasn't seen much information on the new variety previously, the adviser calls up information from several server sites. They look at this and at the characteristics of the test field and discuss the potential yield and the spray strategy the farmer wants to adopt (e.g. high or low risk). They check the list of chemicals they have set up as available and make necessary changes.

They then check the risk ratings for each field i.e. each variety may have a different strategy associated with it, the high quality wheat's may have a low risk strategy and the feed wheat's a medium strategy. The risk level will determine the optimum dose
calculated by the system. After this they look at the weather information used to base growth stages and disease development on. This is based on an average of past years and needs tweaking slightly when they see that the last, very dry, summer has reduced the average rainfall by more than they would expect. Then they add in the current disease levels. When at last they are satisfied that all the information is correct they are ready to produce a plan.

The farmer selects the auto-planner option and they sit back and wait while the system calculates the best spray dates for each of the fields selected. A message box informs them that it has no information on dose response specific to the new variety and ask them if they would like to choose the variety grouping closest to it. The adviser scans the list and finds the one he thinks most closely matches and selects that. A minute later and the planner finishes its calculations.

The screen it now presents shows the months of the year across the top of the window and the fields and varieties down the side. Predicted growth stages and optimal spray dates are shown alongside the field names.

Once they're happy that this is a realistic prediction for the year, then start looking at actual sprays/dates/types. They change the view to look at the detail of each spray and see if it fits their expectations. Where necessary they tweak the rates and timings of the sprays and possibly the choice of chemical. The farmer remembers that he has a sprays worth of chemical x left and wonders if he might use it for the first spray on field K12. The adviser tells him it would be fine and so he changes the chemical name in the spray field. The system immediately throws up a dialogue box explaining that the chemical is not optimal for winter wheat. The adviser tells the farmer it is still fine and explains why. On occasion they check the reasoning behind an optimum date.

Changing an individual date alters the following dates for a given field but does not affect the dates for other fields. Hitting 'undo' restores the previous setting.

When they are both happy that the plan is as good as it can be they select the calculate option and the system calculates the requirements for different chemicals throughout the year. A summary table is displayed. If there is any choice in supplier they look at pricing information and make decisions as to where they will source the materials and when they should be purchased.

One order is required very soon so the farmer selects the relevant columns and hits the mail order option. An email or fax template appears with the chemical requirements already entered into it. The contact details for the supplier are selected from the farmers on-line address book.

The plan for the year is saved and printed out and a copy is forwarded to the advisers address. After the adviser has gone the farmer sits down again and runs through the plan again, this time looking at what might happen if there is another very dry year or if the levels of disease are very high.
Full system - Tactical decision at GS39
The consultant arrives at a farm for a regular fortnightly visit. The consultant is fairly up-to-date with what has been happening in the fields because they checked the spray records and farmers observation notes for the farm before leaving the office that morning.

The farmer and consultant sit down and go through the route they want to cover on the field walk that day, making sure that they will cover all the main areas of concern. During this discussion the consultant mentions that she noticed that field K25 hadn't been sprayed on the date they'd agreed, the farmer explains that it was due to the mechanical failure of the sprayer which will only be back in use later that week. They agree to pay special attention to that field and look at the effects of missing a spray.

The farmer tells the consultant that he would like to reduce the doses they'd agreed on the spray plan because he thinks it has been a good year. He's already checked it out on the spray planner and displays the recorded plan, but he want to check his interpretation of the level of disease with the adviser.

The consultant says that it looks good but that they would need to check the fields first. The farmer prints out the revised plan to bring with them.

The consultant checks the crops for growth stage, strength, colour, weeds, pests and diseases. On most fields it conforms to the farmers estimations quite well, however one field looks a little more vulnerable and they have to change the strategy to cope with the raised levels of diseases in the unsprayed field. The new levels are noted on the farmers sheet as well as on the consultant notepad (computer or paper - if paper then the new data could be entered into the portable each time they get back into the car).

When they get back to the farm, they download or type in the new data into the farmers latest plan, note the savings the adjustments have made, and save as the new spray plan.

The farmer then recalculates and adjusts the next chemical order according to the new figures.

Full system - Tactical GS59, Ear Spray
Adviser comes round for fortnightly visit.
Has been raining rather hard over the previous week, and there is a medium risk milling variety in this particular field (is a high potential yield crop with a good price). The adviser does not have any specific info. on rainfall in this locality, because it is a bit of a far flung farm.

The farmer and adviser discuss this issue, and then check on the farmers local weather data to see if there has been more than 10mm over the last 3 days. Also checks to see if chlorothalonil was included in the flag spray, which it was.

The adviser thinks this through and decides that the field needs to be walked before a decision can be made, although it seems likely that a spray is needed.
They go out to the crop, and find some disease, but it is still a borderline decision. They come back to the office and run a cost analysis on it using the spray planner, they run a 'what if' with and without the morpholine, and with and without the spray. On checking the gross margins they decide it is economically sensible to spend the money.
5.0 DESSAC context
This document is primarily concerned with the winter wheat fungicide module WWFung. However the project recognised that it had to be aware of the whole farm context in which DESSAC and WWFung would be operating. WWFung and other DESSAC modules will not be used in isolation, but as additions to an established set of methods used to deal with all types of decision. Failure to acknowledge these wider and potentially more important decisions might result in a tool which was so specialised and marginal that it would be used as a novelty rather than a regular part of the decision making process.

Table 1: Showing decisions farmers selected as important to the farm

<table>
<thead>
<tr>
<th>Decision Area</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input related decisions</td>
<td>170</td>
</tr>
<tr>
<td>Finance related decisions</td>
<td>134</td>
</tr>
<tr>
<td>What cropping plan/rotation to adopt</td>
<td>103</td>
</tr>
<tr>
<td>What variety of crop</td>
<td>77</td>
</tr>
<tr>
<td>Machinery decisions</td>
<td>47</td>
</tr>
<tr>
<td>When to drill</td>
<td>37</td>
</tr>
<tr>
<td>Ensuring timeliness - of all activities</td>
<td>29</td>
</tr>
<tr>
<td>Labour - identifying labour requirements and making effective use of labour</td>
<td>28</td>
</tr>
<tr>
<td>Cultivation techniques</td>
<td>21</td>
</tr>
<tr>
<td>When to harvest</td>
<td>19</td>
</tr>
<tr>
<td>Soil management</td>
<td>10</td>
</tr>
<tr>
<td>(123 respondents)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Consultants important whole farm decisions

<table>
<thead>
<tr>
<th>Decision area</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticide choice/rate/timing</td>
<td>6</td>
</tr>
<tr>
<td>Fertiliser strategy/rate</td>
<td>6</td>
</tr>
<tr>
<td>Cropping/rotation</td>
<td>5</td>
</tr>
<tr>
<td>Variety</td>
<td>4</td>
</tr>
<tr>
<td>Machinery/labour planning</td>
<td>4</td>
</tr>
<tr>
<td>Financial planning &amp; marketing</td>
<td>4</td>
</tr>
<tr>
<td>Drilling date</td>
<td>3</td>
</tr>
<tr>
<td>Timing</td>
<td>3</td>
</tr>
<tr>
<td>Cultivation</td>
<td>2</td>
</tr>
</tbody>
</table>

(1 missing data point)

In the 1995 Postal Survey respondents were asked to list the top 10 decisions on the farm. The results, shown in tables 1 and 2 above, list the results by the number of people who suggested them and it would seem that financial planning, choosing varieties and marketing were important to a large number of people. General management decisions such as spray timing were also mentioned by a high number of respondents.
While the results of the survey seemed to confirm that the decision to tackle fungicide applications was well founded it also underlined the importance of including other information not directly related to timing and rate. The need to link the fungicide module in with financial planning information and to make it easy to access other types of information has also been supported by the user workshops.

To summarise, the types of information that WWFung should incorporate or at least permit easy access to are:

- **Financial information**
  - e.g. all data relating to past and expected performance, input costs, etc. The facility to calculate new costs and impact on margins is an essential part of the 'what if decision process.'

- **Variety information**
  - e.g. data from NIAB or other sources. The ability to sort the data on the factors that the user feels are critical (e.g. resistance) will make the provision of this information on screen more useful than the paper based source.

- **Farm records**
  - e.g. spray records, yield records, drilling dates etc. Making this information available within WWFung without the need for the user to re-enter it will make it very attractive to the user.

- **Market information**
  - This information is not directly required within the module but access to it while using WWFung would be useful.
6.0 **Hardware requirements**

User requirements for the hardware were collated from the face to face interviews. While the speed of change in the hardware industry is too fast to allow the project to specify systems in any detail, the main requirements at the current time seem to be:
- Portability: access to computer facilities in the car, field, home and office.
- Inclusion of portable printing facilities for advisers.
- Communication facilities (links to office and Internet).

The ideal machine is likely to be a powerful portable P.C. capable of storing the wide range of information required by advisers and fast enough to cope with the calculations farmers may require when using their simulation tools and gross margin calculations. It would have an in-built modem and fax/printer facility and could be used as, or in easy conjunction with, a portable in the car and at home.

A pen based notebook would be ideal for field use, allowing rough sketching and form filling activities to take place. These files could then be downloaded into the portable for incorporation into farm records, customer reports etc.
7.0 Usability evaluation criteria
This section describes the criteria by which the WWFung module and its associated
information sources will be evaluated.

Usability is measure of the ease with which a system can be learned or used, its safety,
effectiveness and efficiency, and the attitude of its users towards it (Preece, 1993). While
the majority of this document has been directed at the statement of requirements and
therefore at the specification of the system, this section looks further ahead at the
evaluation process and specifically at the means by which the requirements can be used
in testing. Many of these criteria can be used to test other modules at a later stage and it
is intended that this section be expanded during the lifetime of the project to become a
template for evaluation.

7.1 Questions
The first section in this report identified a set of questions which the users need answers
to when they are making decisions about winter wheat fungicides. These questions can
also be used to test the system during development. If the design can be shown to be
capable of coping with all of the most highly rated questions then it will have gone a
long way towards demonstrating its effectiveness as a decision support tool.
Demonstrating support for key questions could be a generally applicable evaluation
guideline.

7.2 Usability principles
The following is a brief description of the usability principles that will be used during
expert evaluations of WWFung or associated information modules. More
comprehensive coverage of these and other usability aspects are covered in the
introduction to the Windows guidelines.

Ease of use
Users' reactions to a new system will be affected a great deal by how straightforward it
appears to be to use. If it appears to work in a natural way, which can easily be
understood, then users will react favourably towards it and its chances of success will be
greater. If, however, the system seems unnatural and difficult to understand, users will
be unenthusiastic and will fail to use it effectively (only computer enthusiasts regard
complex systems as a challenge).

Labour Saving
People will expect a computer system to help them do their work more easily and will be
disappointed if their jobs become harder or more tedious. The system should avoid
involving the user in irritating procedures or unnecessary effort. Indeed, the overhead
of learning to use the system should be perceived by the user as a worth-while
investment. Provision of shortcuts is an important issue concerned with labour saving.
Users should be able to carry out common actions, requiring multiple key presses,
through the use of short cuts e.g. using type ahead, special codes, etc. The use of default
values is particularly relevant to DESSAC.
Clarity
Cluttered presentation of information is equivalent to a person speaking incoherently. Similarly, the use of unfamiliar terms and computer jargon presents a barrier to the user. The dialogue should present information clearly and use language which is understandable to the user.

Consistency
Having gained some knowledge by using one part of a system, users will expect to be able to apply this throughout the system. It is particularly frustrating for a user to have to use apparently similar facilities in different ways. The effect is similar to that of a car driver having to relearn dashboard controls and displays when he/she buys a new car. Consistency at the human-computer interface provides the user with a greater return on his or her 'investment' in learning how to use it. If commands, functions and screen layouts are consistent throughout the system then users became accustomed to interacting with the system more quickly than if the software contains inconsistencies.

Tolerance
Intolerance within a computer interface is perhaps the most annoying feature of human computer interaction (e.g. forcing users to input data in a fixed order, whilst rejecting other, perfectly natural, orders). This is often difficult to accommodate whilst still ensuring that the system is designed consistently. However, users will make mistakes whilst using the computer and their attitude to the system will be influenced in part by how easy it was to correct that mistake.

Error tolerance
The provision of a 'safe' environment will allow users to explore or try guesses if they feel that they will not crash the system or lose data.

Helpfulness
At some point within a dialogue the user will be unsure how to proceed and will need assistance. It may not always be convenient to seek help from another user and so the ability to provide system help when needed is important. The Windows environment provides an excellent context specific mechanism for providing this assistance.

Feedback
The system should always provide feedback to user inputs. Depending on the type of input the feedback can simply indicate that the system has received the user input (e.g. the correct character appears on the screen; audible feedback of key press, etc.) or a more complex message that the system is processing the user input could be provided. At no time should the user be in state of uncertainty as to whether the system has received his/her input.

Flexibility
There are two aspects of dialogue flexibility. Firstly, it can provide different ways of working for users with different levels of experience. Novice users will require an explanatory, clearly staged dialogue while experienced users will prefer briefer, quicker ways of working. Secondly, the dialogue should be easily modifiable to accommodate changing procedures and user requirements.
Minimal load on human short term memory

Human short term memory has only a limited capacity. Dialogues should be designed so as not to overload short term memory (e.g. the dialogue should not require the user to choose from an excessive number of menu items; nor should it require the user to remember numbers or characters from one screen to another, etc.). As a rule of thumb, human short term memory can comfortably accommodate no more than 7 items at any time and for a limited time, about 20 seconds.
8.0 Style Guide

To maximise learnability and reduce complexity the project will have to identify a set of features which have to remain constant from one screen/module to the next e.g., standard terms or font usage. The project has taken the decision to design according to Windows '95 style guidelines which can be found in very accessible form in (Microsoft, 1995). While the guidelines are fairly comprehensive there are still areas which require specific project styles to be laid down. These styles have yet to be defined but could be collated and presented at this point in future versions of the requirements document. The styles which have been agreed are as follows:

- The project title, DESSAC, should always be given in uppercase.
- Disease names in common usage should be given in lowercase e.g. septoria tritici is a commonly used description of a disease and should therefore be presented in lowercase.
- If the causal organism of the disease is being referred to then the name should be italicised and the first word should begin with a capital letter.
- The word 'dose' and not the word 'rate' should be used to refer to the level of chemical applied, or to be applied.
References


User Requirements Document
APPENDICES
A.1 Questions and Information in order of perceived importance

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4*</td>
<td>What questions will the user need answers to at this point in the season?</td>
<td>What information will users need access to in order to answer the questions.</td>
</tr>
<tr>
<td>1</td>
<td>Is there Septoria in the crop?</td>
<td>Inspection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weather</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is leaf 3 emerging?</td>
</tr>
<tr>
<td>1</td>
<td>What is the best strategy for this field/variety?</td>
<td>Trials data especially local Market information</td>
</tr>
<tr>
<td>1</td>
<td>What is the most effective dose for my purposes?</td>
<td>Dose response curves</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Date of application</td>
</tr>
<tr>
<td>1</td>
<td>Will these chemicals mix? e.g. Opus with Cheetah?</td>
<td>Pesticide manual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Green book, pesticide register</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Label information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Own notes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manufacturers technical manuals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Farmers Weekly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(need for a specific module to answer this question - info not currently available in easy to access form.)</td>
</tr>
<tr>
<td>1-2</td>
<td>Are there any specific restrictions with this chemical e.g. not spray near a watercourse?</td>
<td>Pesticide manual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Green Book, labels and pesticide register</td>
</tr>
<tr>
<td>1-2</td>
<td>Do I need to apply fungicide?</td>
<td>Disease presence - 'easily found'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trials data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local information and geographical risk</td>
</tr>
<tr>
<td>1-2</td>
<td>Do I need to spray against eyespot?</td>
<td>Is it present?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Growth stage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crop health/condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is anything else being treated (going through anyway)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Action at 30/31 (previous action)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Previous cropping</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level in field</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drilling date</td>
</tr>
<tr>
<td>1-2</td>
<td>Do I need to spray for septoria, yellow rust or mildew?</td>
<td>Disease presence (easily found and spreading for Mildew and easily found for Rust)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Growth stage, leaf emergence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trials results</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variety risk rating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Current and recent past weather conditions - particularly rainfall</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Past weather conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Past crop info (spray sheet, comments)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Action at 30/31, Drilling date</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean of last 3 years</td>
</tr>
<tr>
<td>1-2</td>
<td>Do I need to use a protectant as well?</td>
<td>Target leaves emerged at time of spray?</td>
</tr>
<tr>
<td>1-2</td>
<td>Has rainfall incident occurred?</td>
<td>Recent past weather</td>
</tr>
<tr>
<td>1-2</td>
<td>Is this chemical available from my stockist?</td>
<td>Supplier information</td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>Consideration</td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1-2</td>
<td>Should I add a morpholine to the main fungicide?</td>
<td>Disease presence</td>
</tr>
<tr>
<td>1-2</td>
<td>Should I spray to control diseases of the ear? (Fusarium, sooty moulds, black-point, ergot)</td>
<td>Growth stage, Variety, Weather</td>
</tr>
<tr>
<td>1-2</td>
<td>What are the financial implications of this decision?</td>
<td>Cost of spray, Margin over spray cost</td>
</tr>
<tr>
<td>1-2</td>
<td>What impact will the current weather conditions have on my spray choice, decision e.g. should I put on more, less or wait?</td>
<td>Label, Pesticide register, Eradicant activity of chemicals</td>
</tr>
<tr>
<td>1-2</td>
<td>What impact will this decision have on my margin over spray cost?</td>
<td>Margin over spray model</td>
</tr>
<tr>
<td>1-2</td>
<td>What is the likely loss if I do nothing?</td>
<td>Yield records for indiv. fields, varieties</td>
</tr>
<tr>
<td>1-2</td>
<td>Which of the available chemicals is the best for the job?</td>
<td>Grouping of products in efficacy terms</td>
</tr>
<tr>
<td>1-2</td>
<td>Which of these chemicals is the most cost effective?</td>
<td>Cost of Chemical, Tank mix, Cost of time changes - need for increased dose if spray later, Potential yield loss from not spraying now, The lowest dose for effective control, taking into account: Time, GS, Variety, Yield potential - market and market value, Disease pressure (Sowing date, Crop canopy structure, Weather (pre), Weather (post), Soil factors (type))</td>
</tr>
<tr>
<td>1-2</td>
<td>Which product/active could I use for this problem?</td>
<td>Availability, Green Book (not complete), Pesticide register, Cost (use price bands, or pick up from previous year or pick up from user entered information), Activity level of active/product (trials)</td>
</tr>
<tr>
<td>2</td>
<td>Can I delay my 'flag-leaf' spray until GS59?</td>
<td>Disease in crop, Recent weather conditions, Variety</td>
</tr>
<tr>
<td>2</td>
<td>Do I use home saved or certified?</td>
<td>Survey information, general health status, own test results, likely date of sowing, Weather (past, current season - especially June), Weather after harvest if it is to be a second wheat, Weather during flowering</td>
</tr>
<tr>
<td>2</td>
<td>Does the recent past/current weather affect the present decision?</td>
<td>Label, pesticide register, pesticide manual for effect of weather on performance, Models showing effect of weather on disease development</td>
</tr>
<tr>
<td>2</td>
<td>How does spray A compare against spray B?</td>
<td>Dose response curves, Cost</td>
</tr>
<tr>
<td>No.</td>
<td>Question</td>
<td>Resource/Method</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2</td>
<td>How long till flag leaf fully emerged</td>
<td>Growth model</td>
</tr>
<tr>
<td></td>
<td>What are chances of disease spread in that time</td>
<td>How long has leaf 2+3 been out</td>
</tr>
<tr>
<td>2</td>
<td>If I leave the spray for 'X' days which is the best chemical/dose then?</td>
<td>Chemicals listed in eradicant activity order</td>
</tr>
<tr>
<td>2</td>
<td>Is seed treatment compatible with insecticide?</td>
<td>Label information</td>
</tr>
<tr>
<td>2</td>
<td>Is this variety susceptible to this disease? or What is the risk posed by disease</td>
<td>NIAB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local trials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Geographic risk</td>
</tr>
<tr>
<td>2</td>
<td>Should I apply an ear-spray?</td>
<td>Disease presence</td>
</tr>
<tr>
<td>2</td>
<td>Should I treat the seed?</td>
<td>Is it home saved or certified</td>
</tr>
<tr>
<td>2</td>
<td>What are the safety considerations with this choice?</td>
<td>Pesticide manual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Green Book, labels and pesticide register</td>
</tr>
<tr>
<td>2</td>
<td>What diseases are my varieties susceptible to?</td>
<td>NIAB ratings, local trials, local risks</td>
</tr>
<tr>
<td>2</td>
<td>What fungicides should I buy for the season?</td>
<td>Availability, price</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variety, area of country</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diseases present (for in season decision)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dose response curves</td>
</tr>
<tr>
<td>2</td>
<td>What is the growth stage of the crop?</td>
<td>Drilling date</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weather</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User input (with checks)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Photos/diagrams</td>
</tr>
<tr>
<td>2</td>
<td>What is the window of opportunity for spraying as of now (today)?</td>
<td>User records of machine availability etc</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weather forecasts</td>
</tr>
<tr>
<td>2</td>
<td>What other crops can this chemical be used on?</td>
<td>Pesticide manual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Green Book, labels and pesticide register</td>
</tr>
<tr>
<td>2</td>
<td>When was the last spray date and what did I use?</td>
<td>User records</td>
</tr>
<tr>
<td>2</td>
<td>When will leaf 3 emerge? i.e. do I need to spray against Septoria?</td>
<td>Date of drilling,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Temp. in April &amp; May.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Growth stage model ideally)</td>
</tr>
<tr>
<td>2</td>
<td>Where did this information come from?</td>
<td>Publication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Date</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Abstract of source</td>
</tr>
<tr>
<td>2</td>
<td>Which treatment should I use out of the (possibly 6) available?</td>
<td>Cost, availability of products</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Users judgement of risks (risk last year, test results, weather after harvest)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drilling date.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Area risk rating (mostly yellow rust)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variety risk rating for list of diseases</td>
</tr>
</tbody>
</table>
| 1-3 | What impact will the tank residue have on my next crop? | Pesticide manual  
Green book, pesticide register  
Label information |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2-3</td>
<td>Duration of effect (eradicant and protectant) of chemical?</td>
<td>Needs to be researched from trials data</td>
</tr>
<tr>
<td>2/4</td>
<td>What should I use to reduce resistance of fungal disease to the chemical?</td>
<td>Variety, dose response curves</td>
</tr>
<tr>
<td>3</td>
<td>What is this disease?</td>
<td>Photos, descriptions</td>
</tr>
<tr>
<td>3</td>
<td>Why is that chemical best for this problem?</td>
<td>General information on chemical and disease</td>
</tr>
<tr>
<td>3-4</td>
<td>How do I estimate the extent of this disease?</td>
<td>Keys, DISTRAIN</td>
</tr>
<tr>
<td>4</td>
<td>What problems have I had before, what did I do about them?</td>
<td>User records</td>
</tr>
<tr>
<td></td>
<td>What future steps do I take to avoid disease?</td>
<td>Examples of typical spray programmes</td>
</tr>
</tbody>
</table>
A.2 Questions and information by season

The same questions are now presented in terms of their appearance during the season. Questions which may be asked at any point in the season are provided separately at the end of the table.

<table>
<thead>
<tr>
<th>Decision Point</th>
<th>Rank</th>
<th>Question</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>What time in the growing season is the decision made?</td>
<td>1-4*</td>
<td>What questions will the user need answers to at this point in the season?</td>
<td>What information will users need access to in order to answer the questions.</td>
</tr>
<tr>
<td>Seed</td>
<td>2</td>
<td>Do I use home saved or certified?</td>
<td>Survey information, general health status, own test results, likely date of sowing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weather (past, current season - especially June)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weather after harvest if it is to be a second wheat.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weather during flowering.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Should I treat the seed?</td>
<td>Is it home saved or certified.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Is seed treatment compatible with insecticide?</td>
<td>Label information.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Which treatment should I use out of the (possibly 6) available?</td>
<td>User records: Cost, availability of products. Users judgement of risks (risk last year, test results, weather after harvest) Drilling date.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Area risk rating (mostly yellow rust). Variety risk rating for list of diseases.</td>
</tr>
<tr>
<td>Autumn</td>
<td>1-2</td>
<td>Do I need to apply fungicide?</td>
<td>Disease presence - 'easily found' Trials data</td>
</tr>
<tr>
<td>(Sept. - Jan.)</td>
<td></td>
<td></td>
<td>Local information and geographical risk.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>What is the best strategy for this field/variety?</td>
<td>Trials data esp local Market information.</td>
</tr>
<tr>
<td>Spring</td>
<td>1-2</td>
<td>Do I need to spray against Eyespot?</td>
<td>Is it present? Is anything else being treated (going through anyway) Previous cropping Level in field (incidence)</td>
</tr>
<tr>
<td>(GS 30/31)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring (March/ 3rd week April)</td>
<td>1-2</td>
<td>Should I apply fungicide to control mildew? Should I apply fungicide to control rust?</td>
<td>Disease presence (easily found and spreading for Mildew and easily found for Rust) Trials results Variety risk rating Current and recent past weather conditions - particularly rainfall Past weather conditions Date of sowing</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>What fungicides should I buy for the season?</td>
<td>Availability, price Variety, area of country, Diseases present (for in season decision) Dose response curves</td>
</tr>
<tr>
<td></td>
<td>2/4</td>
<td>What should I use to reduce resistance of fungal disease to the chemical?</td>
<td>Variety, dose response curves.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Is there Septoria in the crop?</td>
<td>User records: inspection Weather, Is leaf 3 emerging?</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>What diseases are my varieties susceptible to?</td>
<td>NIAB ratings, local trials, local risks.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>When will leaf 3 emerge? i.e. do I need to spray against Septoria?</td>
<td>Date of drilling, Temp. in April &amp; May, (Growth stage model ideally.)</td>
</tr>
<tr>
<td>GS31/32</td>
<td>1-2</td>
<td>Do I need to spray for eyespot?</td>
<td>Crop health/condition - Eyespot level Past crop info (spray sheet, comments) Action at 30/31, Drilling date</td>
</tr>
<tr>
<td></td>
<td>1-2</td>
<td>Do I need to spray for septoria, yellow rust or mildew?</td>
<td>Inspection, Crop health/condition Disease level Past crop info (spray sheet, comments) Action at 30/31, Drilling date Weather Varietal susceptibility</td>
</tr>
<tr>
<td>GS32 - 37</td>
<td>1-2</td>
<td>Should I apply fungicide to control septoria? Should I apply fungicide to control mildew? Should I apply fungicide to control rust?</td>
<td>as previous Growth stage, leaf emergence, rainfall</td>
</tr>
<tr>
<td></td>
<td>1-2</td>
<td>Should I apply fungicide to control eyespot?</td>
<td>Growth stage, level of disease in crop Weather conditions</td>
</tr>
<tr>
<td></td>
<td>1-2</td>
<td>Do I need to use a protectant as well?</td>
<td>Target leaves emerged at time of spray?</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>How long till flag leaf fully emerged? What are chances of disease spread in that time?</td>
<td>Growth model How long has leaf 2+3 been out</td>
</tr>
<tr>
<td>GS39</td>
<td>1-2</td>
<td>What is the likely loss if I do nothing?</td>
<td>Yield records for indiv. fields, varieties</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Can I delay my 'flag-leaf' spray until GS59?</td>
<td>Disease in crop Recent weather conditions Variety</td>
</tr>
<tr>
<td>GS39 - GS59</td>
<td>1-2</td>
<td>Should I apply fungicide to control septoria? Should I apply fungicide to control mildew? Should I apply fungicide to control rust?</td>
<td>Variety, weather, disease presence Trials results Mean of last 3 years</td>
</tr>
<tr>
<td></td>
<td>1-2</td>
<td>Should I apply an ear-spray?</td>
<td>Variety Weather Disease presence</td>
</tr>
<tr>
<td></td>
<td>1-2</td>
<td>Should I add a morpholine to the main fungicide?</td>
<td>Disease presence</td>
</tr>
<tr>
<td>GS59- harvest</td>
<td>1-2</td>
<td>Should I spray to control diseases of the ear? (Fusarium, sooty moulds, black-point, ergot)</td>
<td>Growth stage Weather</td>
</tr>
<tr>
<td>ANYTIME Tank mix questions</td>
<td>1</td>
<td>Will these chemicals mix? e.g. Opus with Cheetah? If they don't mix what should I do? What alternatives are there? What is definitely excluded in tank mixes Because illegal Because will kill/damage crop Chemicals physically incompatible i.e., solidify when mixed</td>
<td>Pesticide manual Green book, pesticide register Label information Own notes Manufacturers technical manuals Farmers Weekly (need for a specific module to answer this question - info not currently available in easy to access form.)</td>
</tr>
<tr>
<td></td>
<td>1-3</td>
<td>What impact will the tank residue have on my next crop?</td>
<td>Pesticide manual Green book, pesticide register Label information</td>
</tr>
<tr>
<td>Product questions</td>
<td>1-2</td>
<td>Which product/active could I use for this problem?</td>
<td>Availability</td>
</tr>
<tr>
<td>-------------------</td>
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<td>-------------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Green Book (not complete)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pesticide register</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cost (use price bands or pick up from previous year or pick up from user entered information)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Activity level of active/product (trials)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>How does spray A compare against spray B?</td>
<td>Dose response curves, cost</td>
</tr>
<tr>
<td>1-2</td>
<td></td>
<td>Which of the available chemicals is the best for the job?</td>
<td>Grouping of products in efficacy terms</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>What other crops can this chemical be used on?</td>
<td>Pesticide manual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Green Book, labels and pesticide register</td>
</tr>
<tr>
<td>1-2</td>
<td></td>
<td>Is this chemical available from my stockist?</td>
<td>Supplier information</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>What is the most effective dose for my purposes?</td>
<td>Dose response curves</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Date of application</td>
</tr>
<tr>
<td>1-2</td>
<td></td>
<td>What impact will the current weather conditions have on my spray choice/decision e.g. should I put on more, less or wait?</td>
<td>Label, Pesticide register, Eradicant activity of chemicals</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>If I leave the spray for X days which is the best chemical/dose then?</td>
<td>Chemicals listed in eradicant activity order</td>
</tr>
<tr>
<td>2-3</td>
<td></td>
<td>What is the duration of effect (eradicant &amp; protectant) of this chemical?</td>
<td>Needs to be researched from trials data.</td>
</tr>
<tr>
<td>Disease</td>
<td>3</td>
<td>What is this disease?</td>
<td>Photos, descriptions</td>
</tr>
<tr>
<td></td>
<td>3-4</td>
<td>How do I estimate the extent of this disease?</td>
<td>Keys, DISTRAIN</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Is this variety susceptible to this disease?</td>
<td>NIAB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or What is the risk posed by disease?</td>
<td>Local trials</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Geographic risk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What future steps do I take to avoid disease?</td>
<td>Examples of typical spray programmes</td>
</tr>
<tr>
<td>Legislation</td>
<td>1-2</td>
<td>Are there any specific restrictions with this chemical e.g. not spray near a watercourse?</td>
<td>Pesticide manual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Green Book, labels and pesticide register</td>
</tr>
<tr>
<td>Safety</td>
<td>2</td>
<td>What are the safety considerations with this choice?</td>
<td>Pesticide manual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Green Book, labels and pesticide register</td>
</tr>
<tr>
<td>Financial</td>
<td>1-2</td>
<td>What impact will this decision have on my margin over spray cost?</td>
<td>Margin over spray model</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Which of these chemicals is the most cost effective?</td>
<td>Cost of Chemical, Tank mix</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cost of time changes - need for increased dose if spray later</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Potential yield loss from not spraying now</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The lowest dose for effective control, taking into account: Time, GS, Variety, Yield potential - market and market value, Disease pressure (Sowing date, Crop canopy structure, Weather (pre), Weather (post), Soil factors (type))</td>
</tr>
<tr>
<td>1-2</td>
<td></td>
<td>What are the financial implications of this decision?</td>
<td>User records: Cost of spray</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Margin over spray cost</td>
</tr>
<tr>
<td>Misc</td>
<td>4</td>
<td>What problems have I had before, what did I do about them.</td>
<td>User records</td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>Data Required</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>What is the growth stage of the crop?</td>
<td>Drilling date, Weather, Variety, User input (with checks), Photos/diagrams (or model)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Why is that chemical best for this problem?</td>
<td>General information on chemical and disease</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>When was the last spray date and what did I use?</td>
<td>User records</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Where did this information come from?</td>
<td>Publication, Date, Abstract of source</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Does the recent past/current weather affect the present decision?</td>
<td>Label, pesticide register, pesticide manual for effect of weather on performance, Models showing effect of weather on disease development</td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td>Has a rainfall incident occurred?</td>
<td>Recent past weather</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>What is the window of opportunity for spraying as of now (today)?</td>
<td>User records of machine availability etc, Weather forecasts</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX H:
DESSAC Laboratory Trials


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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Phase I - User Validation

Laboratory trials

Version 1
i Credits

i.i Documentation
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ii Using this document

ii.i Purpose
The purpose of this document is to make available the results of the first phase user validation trials. There are two parts to the document, the first contains the summarised data and will be provided to all DESSAC partner sites, the second contains the collated data from the trials and the materials used within it. The latter document will not be of interest to all parties and will therefore only be made available on request or by downloading from the DESSAC server.

ii.ii Audience
The first part of this document is intended for use by all members of the consortium. The appendices are available for all but will only be distributed on request.

ii.iii How to Use This Document

ii.iii.i Organisation
The introduction to this document, Chapter 1, describes the purpose of the laboratory trials. The method by which the trials were conducted is described in Chapter 2. Chapter 3 presents the results in the most succinct form it was possible to produce without losing the essence of the participants comments. The section is still quite large and is broken down into the specific areas of interest identified by the consortium prior to the trials. Chapter 4 provides a brief discussion of the main findings.
ii.iii.1 Reference aids

Phase 1 - User Validation Trials has adopted the DESSAC style Guide to make information more readily available. The following features will help you find the information you need.

Table of contents lists section titles and major subheadings with page numbers

List of problems lists all the main problems identified within the system under headings relating to their component source.

ii.iv Conventions

This document adopts the style recommended by *The DESSAC Style Guide for paper based documentation*.

ii.v Accompanying documentation

Items referred to as appendices are contained in a separate document to avoid the unnecessary distribution of paper. The appendices contain all the background materials to this report i.e. questionnaires, trial script, user profile and summarised data.
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1 Introduction

This document contains the results of the first set of validation trials for the DESSAC system. The validation phase of the DESSAC began in December 1997 and forms the third part of the user groups contribution to the project; where part one of was the identification of user requirements and part two was refining the requirements and feeding them into the functional specification and design of the interface.

The results of the requirements surveys can be found in project documents UNG 1.0, 2.0 and 3.0, and the requirements specification which resulted from these surveys can be found in UNG 5.0.

The project has continually returned to the industry during the design phase to check its progress. Early prototypes of the DESSAC system were produced and demonstrated to potential users in December 1995 (UNG 4.0) and user involvement has continued in the form of workshops, demonstrations and consultation group activities.

By February 1998, the first non-prototype version of the system was available for user testing. Although this version was not completely functional, enough of the Shell and WDM module were available to allow controlled laboratory testing with users. The rest of this document describes the background, procedure and results of these laboratory trials.
2 Method

2.1 Design  

The purpose of the laboratory trials was to test the first available working version of DESSAC with its intended end users in a controlled setting.

2.2 Users  

Criteria for selection of users for these trials was that they had no previous experience of the DESSAC system; were fungicide decision makers, computer literate, and willing to give up 1.5 hours of their time to the project. Geographical location was not seen as important at this stage. To ensure that a representative sample was obtained several users (3) from within 6 groups key groups were required (18 in total). Table 2.1 illustrates the categories.

<table>
<thead>
<tr>
<th>Table 2.1: Categories of users within the trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmers</td>
</tr>
<tr>
<td>Consultants</td>
</tr>
</tbody>
</table>

Invitations to participate were issued via members of the User Consultation Group and Farmplan/Optimix. Two large scale calls for subjects were issued by ARC (1000 recipients of their newsletter) and from Farmplan/Optimix. From these sources representative members of the intended end user population were selected.

2.3 Materials  

The HUSAT usability laboratory and its recording equipment were used for the trials; video equipment, monitors, a mixing desk and a VHS video recorder to record the final mixed video. The usability lab comprises two main rooms with several adjoining ante-rooms. The two main rooms are separated by a two-way mirror and a door. Figure 2.1 illustrates the room layout for the trials.
The DESSAC system was installed on a Dan multimedia PC (300 MHz, 64Mb RAM). A hand held micro cassette recorder was used for back-up.

Three questionnaires were designed for use during the trial for: a) gathering basic biographical data about the participant b) answering specific system related questions during the trial and c) obtaining feedback from the participant after the trial. Copies of these questionnaire can be found in a separate document containing the appendices. A recording sheet was also developed for use by those observing the trials.

The laboratory was staffed by 2 or 3 personnel at all times. One person to guide the participant through the trials and the other(s) to manage the recording equipment and make observations. Personnel were provided by HUSAT and by Silsoe Research Institute (Simon Beaulah).

2.4 Procedure

2.4.1 Contact and booking procedure

The individuals identified by the means described in section 2.2, meeting the selection criteria, were contacted and briefed prior to the trials. Individual contact allowing them to ask questions of the experimenters e.g. about the purpose of the trials, what they would be doing, how long it would take etc. The date of the trials was set for the middle to end of February as a compromise between technical partners requirements and user availability. Slots within the dates available were offered on a first come first served basis. Participants were sent joining instructions and a brief summary of the DESSAC project by post. Most participants also received a 'memory' jogging telephone call the day before they were due to arrive.

2.4.2 Procedure

Each participant was met at the HUSAT main reception and then to the building in which the usability laboratory is housed. Once there, they were offered refreshments in the ante-room, and asked to fill in the pre-trial questionnaire.
After completing the questionnaire, the purpose and format of the trial was explained to the participant in more detail. The participant was then introduced to the main laboratory and the location and purpose of the recording equipment. The recording equipment was activated just prior to the start of the trial.

A script format was used to guide the user through the software (see separate appendices document). It began with a general explanation of the components of the Shell, explored the farm navigation component in some detail before looking at the WDM module, the encyclopaedia and the variety listings. Where possible the user was asked to carry out tasks (see appendices document) to enable them to have some hands-on experience. The participant was asked questions relating to each component immediately after the task or demonstration for that component. The responses were manually recorded.

At the end of the trial (duration of 60-90 minutes) the participant was asked to complete a final questionnaire, which took a further 15 minutes. The participant was then taken through to the control room, shown the observation equipment and introduced to the observer. The participant was encouraged to ask any questions at this point, and thanked for taking part in the trial.

2.4.3 Analysis

For each participant a set of data was collected. This consisted of:-

- Pre-trial questionnaire
- Questionnaire used during the trial
- Post-trial questionnaire
- Observation sheets
- Video & audio recordings

The summarised questionnaire and observation data is available in the appendices document. The video and audio data has been used to supplement the written data, but is not contained in the appendices. The results section contains condensed and collated data from all of the trials, organised to relate to specific questions or areas of interest to DESSAC developers.
3 Results

3.1 Participant details 6

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3.2.2 Utility

3.2.2.1 Usefulness

3.2.2.2 Role of DESSAC as a decision tool

3.2.2.3 Reliability

3.2.3 Attitude to the DESSAC system

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3.2.4 Need for training & help

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3.5.2.2 Date bar

3.5.2.3 Spray indicator

3.5.2.4 Spray plan dialog

3.5.2.5 Tabbed area - Canopy management
3.1 Participant details

Two of the 18 participants were unable to attend, and given the short notice provided and the limited time available, they were not replaced. Table 3.1 shows the distribution of those who participated.

<table>
<thead>
<tr>
<th>Categories of users within the trials</th>
<th>Farmers</th>
<th>Consultants</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 * 0-300ha</td>
<td>2 * 300-800</td>
<td>3 * 800+</td>
</tr>
<tr>
<td>2 * 300-800</td>
<td>3 * Independent</td>
<td></td>
</tr>
<tr>
<td>3 * 800+</td>
<td>3 * Distributor</td>
<td></td>
</tr>
</tbody>
</table>

The data described in the following sections has to a large extent been collated and summarised from free text.

3.2 Usability

3.2.1 Ease of Use (interface summary)

On the whole the response from participants to questions of usability were very positive. Participants found the system logical, quick and easy to use, user friendly and accurate, allowing more information than could usually be held in the head to be taken into consideration when making a decision. User friendliness was cited by 3 participants when asked ‘What did you think was the best part of the system’. Comments suggested that they thought that DESSAC would make decision making easier, would provide more justification and clarification, improving the quality of decision making and removing the guesswork. They also appreciated being able to see the implications of decisions.

Two users said they would find the system more difficult in that decision making would take longer, however they also thought the final decision would be better and more accurate, and there would be more confidence in the decision reached.
One user thought that the system was more complicated than other systems with less help. It should be noted however that at the time of testing the on-line help had not been implemented.

Most participants seemed to feel that initial problems with the system were due to a lack of familiarity with the system rather than real problems with the ease of use of the system. This is understandable, as all participants were completely new to DESSAC and only had 2 hours to learn, use and comment on the system during the trials.

Areas of the system that received particularly positive comments were:

- Ability to use blocks to speed up data entry and decision making
- Comparison screen in optimise.
- Ability to see when chemical cover ends
- Visual aid of the weather, canopy management and growth stage indicators
- Direct link to data held in existing CMS.

There were some specific areas of the system where people felt there were usability problems or thought that information or functionality was missing, and these are specifically addressed in the problem section of this document (Section 3.5)

3.2.2 Utility

3.2.2.1 Usefulness

Participants were asked a number of questions relating to the perceived usefulness of the system and the results of these are discussed below.

Users were asked 'What do you think was the best part of the system', Table 3.2 below summarises their responses.

<table>
<thead>
<tr>
<th>Table 3.2: What did participants feel was the best part of the system?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimising</td>
</tr>
<tr>
<td>What if's &amp; experimenting</td>
</tr>
<tr>
<td>User friendliness</td>
</tr>
<tr>
<td>Predictive nature of system</td>
</tr>
<tr>
<td>Management tool</td>
</tr>
<tr>
<td>Planning</td>
</tr>
<tr>
<td>Prescriptive nature of system</td>
</tr>
<tr>
<td>Yield values</td>
</tr>
<tr>
<td>Flexibility</td>
</tr>
<tr>
<td>Speed</td>
</tr>
</tbody>
</table>

The most popular aspects of the system were: the optimising, 'what if'ing', its user friendliness, and its predictive power. It was felt that the system would allow more confident reduction of chemical rates.

The DESSAC system was seen as supporting questions that people wished to ask, and was perceived to be of help when making decisions. DESSAC was also seen as useful as a teaching aid, and as a forum for discussions between farmer and adviser. As farmers often ask the implications of different actions, as one adviser
said 'I can use it to test farmers ideas in front of them'. They felt it would also support more targeted field walking.

Facilities which were seen as particularly useful were: customisation of chemical lists and being able to block on varieties (one adviser would want to be able to block on a variety across his whole area, not just on one farm).

The pre-season planner screen was referred to as ‘fantastic’ by one user, but was seen as less useful and not as important as the in-season planning screen by other users. This was due to the range of unknowns at that point in the season, especially the weather. However all users want the pre-season functionality to exist.

The varieties information was perceived to be useful, and users were especially interested in selecting varieties based on spraying costs and yield potential.

All users said that all the parts of the system that they had seen were necessary.

On the negative side participants were asked what they thought was the worst part of the system, their responses are listed in table 3.3 below.

<table>
<thead>
<tr>
<th>Table 3.3: What did participants think was the worst part of the system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential time costs</td>
</tr>
<tr>
<td>Nothing</td>
</tr>
<tr>
<td>Lack of integration with other spray tasks</td>
</tr>
<tr>
<td>Split triangles on the optimise screen</td>
</tr>
<tr>
<td>No quick view on the optimise screen</td>
</tr>
<tr>
<td>Computing power/ cost</td>
</tr>
<tr>
<td>Canopy tab</td>
</tr>
<tr>
<td>Encyclopaedia</td>
</tr>
<tr>
<td>Spray indicators</td>
</tr>
<tr>
<td>Screen fonts</td>
</tr>
<tr>
<td>May encourage unnecessary tweaking</td>
</tr>
</tbody>
</table>

There were several participants who had nothing to say in response to this question. Time costs were cited by 4 participants.

Twelve out of the 16 participants cited things they would like to see changed in the system to make it more useful to them. These are available in the 'After trials questionnaire' component of the appendices document and all the points are raised elsewhere in this document.

Participants were asked how they thought the addition of a disease intelligence guide would affect their view of the system:

<table>
<thead>
<tr>
<th>Table 3.4: Usefulness of a disease intelligence guide</th>
</tr>
</thead>
<tbody>
<tr>
<td>It would be nice, but would not affect my decision about buying or using it</td>
</tr>
<tr>
<td>It would make me more likely to buy and use the system</td>
</tr>
<tr>
<td>I do not see the need for a disease intelligence guide</td>
</tr>
<tr>
<td>No opinion</td>
</tr>
</tbody>
</table>

The majority (9) felt that it would be nice but wouldn't affect their decision to buy but 5 said that they felt it would make them more likely to buy it.

Things which the participants said would more likely to make them buy and use the system are listed in table 3.5.
Table 3.5: Things which would make people buy and use the system

<table>
<thead>
<tr>
<th>Cost/cost effectiveness</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reassurance about reliability</td>
<td>4</td>
</tr>
<tr>
<td>Links with other systems</td>
<td>3</td>
</tr>
<tr>
<td>Pressure to reduce inputs</td>
<td>1</td>
</tr>
<tr>
<td>Competitive edge</td>
<td>1</td>
</tr>
<tr>
<td>Support</td>
<td>1</td>
</tr>
</tbody>
</table>

Cost effectiveness is seen as most important closely followed by reassurance about reliability and links with other systems.

3.2.2.2 Role of DESSAC as decision tool

There were different perceptions among users as to how far the decision making process was the responsibility of DESSAC. At one end of the spectrum was the perception that DESSAC is one tool among many that the decision maker utilises to make a decision, at the other was the view that DESSAC should make the decision. Most of the participants views tended towards the former. The danger of the later view is reflected in comments such as ‘Tempts one to think system is God, more persuasive than own opinions’, however only one user actually wanted the system to be totally prescriptive. To counteract the problem it is essential that the marketing of the product stresses the supportive nature of the system.

Users were asked ‘Do you think the system we have described will support the way you make decisions or would you need to change your methods if you were to use it?’

Table 3.6: Will DESSAC support your decision making?

<table>
<thead>
<tr>
<th>Supports present methods</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Would change methods</td>
<td>3</td>
</tr>
</tbody>
</table>

Users who thought DESSAC would change methods cited the way decisions were made, using more information than at present leading to less insurance spraying and more forward planning.

Users were asked ‘If the system was completed as we have described how do you think using it would affect your fungicide decision making?’

Table 3.7: Will DESSAC make decision making easier or harder?

<table>
<thead>
<tr>
<th>Easier</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harder</td>
<td>3</td>
</tr>
</tbody>
</table>

Those who said it would become easier cited having a quicker and more detailed understanding of a situation, it would provide a useful backup tool to their own expertise and generally improve decision making. It may also widen the range of options that would be considered in a particular situation.

Those who said it would become harder cited time constraints i.e. having to use their present methods as well as DESSAC until they had enough confidence in DESSAC to rely on it.

All users agreed that decision making would become more accurate as a result of using DESSAC. This was due to the level of detailed information contained within DESSAC, as long as the information was accurate and the models were reliable.
3.2.2.3 Reliability

The usefulness of DESSAC is related to the confidence that users feel they can place in the information within DESSAC, both the information they have entered and the information that is used to run the model. One user comment was ‘There will always be question marks and people will dispute the trials data that goes in it. But given the organisations behind it, it will be authoritative’.

Users were aware that they were dealing with a developing system and therefore they saw reliability as something that would increase as the system reached completion.

When asked about the level of proof they would need most participants cited field trials. When asked how they would go about testing DESSAC the most popular answers were to compare it against their own, or agronomists, methods and to use it.

<table>
<thead>
<tr>
<th>Table 3.8: How users would test the reliability of the system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compare against agronomist/own methods</strong></td>
</tr>
<tr>
<td>Using it</td>
</tr>
<tr>
<td>Test against historical data</td>
</tr>
<tr>
<td>Replicated trials</td>
</tr>
<tr>
<td>Playing with inputs and looking at result</td>
</tr>
<tr>
<td>Try different spray options on different parts of the field</td>
</tr>
<tr>
<td>Rely on testing by others</td>
</tr>
<tr>
<td>Observe disease levels</td>
</tr>
</tbody>
</table>

The reliability of DESSAC was felt to be highly dependent on good weather information. Some users wanted to be able to interrogate the background information that goes into DESSAC, especially the league table of fungicides, costs and the list of main inputs and how it is graded.

Updating was a major concern for most participants. They felt however that if it were regularly updated it could be very useful for keeping them up-to-date with new chemicals.

The trend of the optimisation results seemed to be right to most users, although the recommendation of Tilt at the suggested rate and timing was felt to be suspect.

Participants were asked if there was anything that would improve their confidence in the system, their responses were as follows:

<table>
<thead>
<tr>
<th>Table 3.9: Would anything improve users confidence in the system?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yes</strong></td>
</tr>
<tr>
<td>Seeing proven trial results</td>
</tr>
<tr>
<td>Regular updating</td>
</tr>
<tr>
<td>Good backup if there are any problems</td>
</tr>
<tr>
<td>Training</td>
</tr>
<tr>
<td><strong>Maybe</strong></td>
</tr>
<tr>
<td>Practise/use</td>
</tr>
<tr>
<td>Regularly updating – ie new chemicals/varieties</td>
</tr>
<tr>
<td><strong>No</strong></td>
</tr>
</tbody>
</table>
3.2.3 Attitude to the DESSAC system

3.2.3.1 Positive comments

The overall attitude to the system was very positive, several users stated that they would like to take the system home with them and start using it immediately. Comments included:-

- 'very keen to use it'
- 'see this as a magnificent and significant step forward'
- 'it is the way forward'
- 'I think this program is terrific: I would like to take it home'
- 'very intuitive'
- 'compared with one or two others it looks very good indeed'
- 'almost too good to be true'
- 'good science and product combinations and weather data, all there together'
- 'an enormous amount of information has gone into it'
- 'has substance behind it'
- 'extremely good'
- 'reassuring to know information is being used and HGCA money is being fed back to you via dessac'
- 'very easy to use – in no way difficult. There is nothing you could not figure out for yourself'
- 'it does exactly what it says. It's a good decision support system'
- 'would like to take it home'
- 'it is something to go back to time and time again'

<table>
<thead>
<tr>
<th>Table 3.10: Is the system what the users expected?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>Maybe</td>
</tr>
<tr>
<td>No</td>
</tr>
</tbody>
</table>

When asked, most users felt that the system was as they expected it.

When asked how they would describe the system to others all participants said they would describe it as 'Good' (rather than Poor or No Opinion) for the following reasons:
"Information can be obtained very easily"

"Easy to use. Will improve accuracy of decision making."

"I believe the system when fully operational will help us (as a company) make better use of our time and will help us justify our decision in view of current crop assurance schemes."

"Easy to use and detailed."

"A very useful tool to support decisions on chemical use"

"Very easy to use and full of very easy to access information which is required on a daily basis."

"Because it should improve my profitability"

"It is the way forward in every way."

"It would help me analyse in greater depth. Useful in prioritising time spent in the field relative to risk. Good tool for demonstrating thinking and logic behind a recommendation."

"Seems sensible and usable and practical but need to compare and use with other criteria important to achieving yield and gross margin."

"It has been well designed and should help the decision making process."

"I enjoyed looking at the system."

When asked if they thought they would use the system themselves when it becomes available, 13 out of the 16 participants said they would, and 3 said maybe. The 'maybes' described their choice as due to company policy and cost.

3.2.3.1 Negative comments

Although the overall reaction was very positive, some reservations were expressed.

Reliability: Many reservations related to the reliability of the models and the need for them to be proven in the field. The robustness of the system was also questioned as failures could undermine the advisers credibility with the farmer.

Local applicability: Participants stressed the need to be able to take into account local conditions, such as soil type, into account, and tweak the system to suit practical needs. They were informed that this would be the case.

Presentation of numerical results: The fact that the system shows exact figures for yield and margin was seen as misleading by several participants. It was suggested that a range was provided instead. The absence of indications of significant differences between options was also felt to be a problem.

Cost: The system must be cost effective to buy and use.

Reduction of adviser role: There was a fear that if farmers bought this system they would start to make their own decisions and will not need advisers in the same way, instead of giving advice they will be given shopping lists.
There were also a number of things which the participants felt were missing from the system that they would expect to find within it, these were as follows:

**Table 3.11: What things were missing from the system**

<table>
<thead>
<tr>
<th>Yes</th>
<th>Growth stage (decimal) and calendar together with weather forecasting</th>
<th>Yield potential of various fields calculated and variety choice made</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Button strip usage – may affect choice</td>
<td>Reference to nitrogen application</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More price/cost data</td>
</tr>
<tr>
<td>Maybe</td>
<td>Information about last treatment detects maximum dose and number of treatments etc.</td>
<td></td>
</tr>
</tbody>
</table>

Other facilities which participants identified as useful during the trial were:

- Costing and buffer strip information as part of the optimise screen
- Information on the version of products, maybe in the spray name area.
- Indication of ear protection.
- Ability to convert from product to active and back again (possible in some circumstances)
- Ability to integrate other pesticide applications (possible if DESSAC compatible)
- A link back to a recommendation programme which would print the chosen option.
- The ability to produce risk factors for an area as well as an individual farm.
- Weed guide and possibly more information on chemicals used in control.
- Printing
- Links to overall financial plan
- Links to other spray decisions
- Links to other systems
- Variety picking facility
- Add to map facility
- Disease diagnosis help
- Disease models
- Weather information
- Find best product facility
- Output to CMS
- A module to pull together cash flow and link to central server.
3.2.4 Need for training and help

Areas where users appeared to need the most help were in 'farm navigation', 'spray plan display area', 'running models', and in 'changing inputs'. Specific problems are described in Section 3.5.

Participants were asked how long they thought it would take them to learn the system.

Table 3.12: How long to learn DESSAC?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Few hours</td>
<td>6</td>
</tr>
<tr>
<td>1-2 days</td>
<td>5</td>
</tr>
<tr>
<td>Not long</td>
<td>2</td>
</tr>
<tr>
<td>Week +</td>
<td>2</td>
</tr>
<tr>
<td>Less than week</td>
<td>1</td>
</tr>
<tr>
<td>Don't know</td>
<td>1</td>
</tr>
</tbody>
</table>

six felt they would need only a few hours and most of the rest less than a week. There was a feeling that a training course would be useful.

Table 3.13: What type of support required?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Telephone helpline</td>
<td>12</td>
</tr>
<tr>
<td>On-screen help</td>
<td>4</td>
</tr>
<tr>
<td>Handbook</td>
<td>2</td>
</tr>
<tr>
<td>Regular updates</td>
<td>1</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>Email help</td>
<td>1</td>
</tr>
<tr>
<td>Courses</td>
<td>1</td>
</tr>
</tbody>
</table>

Participants were also asked what support they felt they needed with the system and why. The majority wanted a telephone helpline.

Observations from the trials provided information about the types of question users will need a help system to provide. They have been organised according to category and included in the appendices document. The headings relate to:

- Entry of data: who puts it in, what is default value and where is it obtained; how often will it be updated and by what means; and specific queries relating to components of the system.
- 'How do I?' type questions i.e. find expected yield, contents of spray plan etc.
- 'Can I?' type questions i.e. do what if's, overlay farm details on map, etc. This was the largest category of questions.
- 'Does it?' type questions i.e. take current weather into account, work out the expense of putting the treatment on.
- Glossary questions i.e. what does 'margin' actually mean.
- 'What happens if I.' type questions i.e. move the spray icon into the past

There were also a number of specific questions relating to the model inputs and to the reliability of the models and to the use of the browser/encyclopaedia.
3.3 Technical questions

These are responses to questions raised by the system developers.

3.3.1 Printing

Users were asked what they would want to be able to print out from the system. The following were specifically mentioned:

- The list of chemicals to carry around, also to create one list for each farmer if a consultant.
- The spray plan options produced by optimising.
- The results of running the model.
- The gross margin figures for the various Optimise options.
- A recommendation sheet, or transfer information to the CMS that produces a sheet.
- Spray plans by field with chemicals and timings.
- A weekly action plan.
- A shopping list of chemical requirements.
- Budgets.
- Status report showing fields at risk.
- Disease risk reports after weather events.
- Stock records.
- Weather information.
- Encyclopaedia information, especially disease and pictures.
- NIAB variety information.
- Justification report.
- Future spray plans at the beginning of the season.
- Individual field/block/variety/species data.

3.3.2 Presentation of uncertainty in margin/yield display

Eleven of the 16 respondents gave the correct explanation of this display on the in-season screen. Five respondents did not give the correct explanation. Of those who gave the wrong description, one, who was prompted to give some answer thought the darkest green area indicated the highest yield, and the others didn’t attempt to guess. This is a good response, as users seemed to either know correctly what was being indicated or knew that they did not know. No-one thought they
knew what was being indicated and was incorrect (which is the most dangerous situation, as if people think they already know they will not look for information, and if they are incorrect, they will continue to be incorrect until something goes sufficiently wrong to encourage them to reassess).

The yield and margin bar information was considered to be very important and needs careful explanation.

One user had the yield and margin and uncertainty information explained to them and then thought that shading the green area was confusing, and it would have been preferable to have a solid green area with the mid-point shown as a figure.

Several participants wanted to know what goes into calculating the margin. There should be an opportunity to enter the cost of spraying if this is not included in the gross margin. It was also felt to be useful to show the margin as a range figure.

One user felt that it would be useful to be able to see the prior display of cost per hectare or tonne next to the current display for comparison purposes.

3.3.3 Timing of and running models overnight

When asked ‘is the time it takes to optimise the spray plan acceptable’, 7 users said yes, 4 said no and 5 didn’t feel able to answer. Comments ranged from ‘very quick’ to ‘too slow’. It was seen to depend on the size and speed of the computer and the time it takes to do each individual optimisation which would become more of a problem if there were several decisions to be taken. When asked what they thought was the limit of acceptable waiting time, participants were generally of the opinion that more than a minute was unacceptable.

Table 3.14: Perceived acceptable run times for optimise function

<table>
<thead>
<tr>
<th>Time Range</th>
<th>Acceptable Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 seconds</td>
<td>2</td>
</tr>
<tr>
<td>20-30 seconds</td>
<td>4</td>
</tr>
<tr>
<td>30 seconds - 1 minute</td>
<td>2</td>
</tr>
<tr>
<td>1 minute - 1 1/2 minutes</td>
<td>1</td>
</tr>
<tr>
<td>2 minutes</td>
<td>2</td>
</tr>
<tr>
<td>5-10 minutes</td>
<td>1</td>
</tr>
</tbody>
</table>

One user said that if they could set the system to optimise all the fields together then 15 minutes would be acceptable.

Participants suggested that an indication of the time the optimisation would take would be useful so they could decide whether to proceed or abandon the action. This would be especially important if advice was being given over the phone or on a visit to a farm. Overall it was felt the system needs to be quick to be useful. There were also comments about the lack of feedback during the models operation.

Users were then asked whether an overnight run would be acceptable for optimising and whether an overnight run would be acceptable for status checks. Overall eleven said yes, 1 said no and four did not feel able to comment.

The main problem with overnight runs was the fear that the computer or DESSAC would crash in the night and the information that was expected would therefore not be available, leaving the user stranded. There would need to be a very high level of confidence in the system, and the computer, and a way to log errors to know what went wrong if it didn’t work. Also having to leave the system running overnight may lead to a perception that the system is slow and cumbersome.

Overnight runs would require leaving the computer on all night, which was not something many users normally do and one user referred to the idea as ‘not
practical'. Other user comments suggested that it would be okay for status checks but not for optimising. One adviser felt that having the results in the morning would not be useful because he would be too busy to make use of the results. This user would prefer the optimising and status checks to run as background processes during the day without interfering with other tasks, making the information available in the evening.

Other users saw no problem in an overnight run, and would want to tie it into back-ups and other tasks. It was seen as possibly a good idea because it would lead to more forward planning, especially the idea of having a complete status check on a Monday morning.

Some advisers would want to do overnight runs on a whole region, not just one farm.

There was a requirement to know how long the activity would take.

### 3.3.4 In-season spray planning display - blob vs. graph

#### Table 3.15: User preferences for blob vs graph display

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Blobs</td>
<td>7</td>
</tr>
<tr>
<td>Graph</td>
<td>4</td>
</tr>
<tr>
<td>Both</td>
<td>2</td>
</tr>
<tr>
<td>No preference</td>
<td>3</td>
</tr>
</tbody>
</table>

The majority of users preferred the 'blob' display, however it should be remembered that the blobs were contained within the working system whereas the graph was presented on paper, therefore the graph was not interactive and could not be seen to change as decisions were taken.

Those that preferred the blobs said that it was easier to see immediately what the blobs meant and disease severity was shown more clearly, which made it easier for advisers to show farmers, and made the need for action more obvious.

One suggested change to the blob display was to show individual disease contributions to the total loss.

Those who preferred the graph display said that it was easier to see thresholds and inputs, and they liked the line which indicated total loss of yield from all diseases. One user stated that although the graph looks more confusing at first it is actually more useful. Some users said graphs were more familiar and allowed them to visualise the situation better.

### 3.3.5 Optimise screen alternatives

During the trial participants were asked whether they preferred a graphical or tabular display for the optimise screen. The majority said that they preferred a graphical display but that the current version needed more information in it. Most users wanted to see the contents of the spray plans and were irritated by having to continually click on the triangles. There were problems selecting a plan, identifying which plans they had already viewed, whether the plans were significantly different from each other. Participants also wanted to return to previous optimise runs and to know what went into the calculation. A number of solutions were suggested and are described in section 3.5.
3.3.6 Weather data

Users were asked the current source of their weather information. Table 3.16 below gives the range of sources that were identified. The numbers are greater than the 16 users that took part in the trials as many users identified more than one source.

| Free sources | Television, radio, Ceefax, looking out of the window, Internet, Morley | 15 |
| Collected personally | By hand, local weather station, HardiPole Metstation, Stephenson screen | 10 |
| Purchased | Local weatherline/ Met Office talkline, | 6 |
| Obtained from other sources | Metfax, Farming on-line, Ocean routes (RBN), Adas Bulletins/intranet | 3 |

6 of the users already buy in weather data, the remaining 10 were asked whether they would be willing to buy in weather data.

| Maybe | 6 |
| No | 1 |
| No answer | 3 |

Six users would not state they were willing to buy in weather data because previously purchased data had been inaccurate. Purchase would depend on the cost and quality of the information, and how much benefit it gives compared with free sources (including the Internet). It would also depend on the sensitivity of the crop to the need to spray, as wheat is quite robust, but other crops may be more vulnerable.

One users concern was that any payment should be a single payment rather than a subscription.

Some users felt that they may purchase a weather station or join a local station network.

One user thought more detailed weather data was needed, such as the time of day a rain event took place.

3.3.7 Varieties information

Users found the varieties information original yet also simple and easy to use. However one user referred to it as ‘adequate, but boring’.

Users would also like to be able to enlarge the view area to be able to see all the information at once as well as maintaining the present format. One user felt that it would be preferable to spread the information out and look at one characteristic at a time.

The yield table was felt to be the wrong way around, in that the best or highest rated variety should be at the top and the worst at the bottom, however the resistance table should definitely be left as it is to prevent expensive mistakes.
Users were asked ‘Would you normally use this type of information to support your decision making’?

Table 3.18: Would participants normally use variety information?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>13</td>
</tr>
<tr>
<td>Maybe</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>No answer</td>
<td>3</td>
</tr>
</tbody>
</table>

13 users said that they would use this type of information, especially at the planning stage, and it was a fundamental part of their decision making.

There was a real need to have up-to-date information on varieties.

Some users mentioned using NIAB and ARC lists as not all varieties were on the HGCA list.

One user said that they kept this kind of information in their Psion as their computer was too slow.

Standing power, quality, yield (treated and untreated) specific rate reliability and milling were all mentioned as factors that were taken into consideration, and the final decision was an interrelation between all these factors. Users stated they wanted as much information as possible.

Users would like to be able to enter parameters in a sort table and then find those varieties that meet their criteria as well as being able to look through the tables.

Users would also like to be able to block on a number of varieties and then work with the selected varieties.

Also there should be the opportunity to perform a primary and secondary sort on the information.

There should be a clearer distinction between the tab for the table you are using and the others.

It was felt to be confusing to see the encyclopaedia start up page before the varieties information appeared, especially as the selection buttons are so close to each other.

3.3.8 The encyclopaedia

Users were asked how they rated the information within the encyclopaedia:

Table 3.19: Usefulness of the level of information within the encyclopaedia

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>About right</td>
<td>11</td>
</tr>
<tr>
<td>No answer</td>
<td>3</td>
</tr>
<tr>
<td>Not detailed enough</td>
<td>2</td>
</tr>
<tr>
<td>Too detailed</td>
<td>0</td>
</tr>
</tbody>
</table>

Most users thought the level of information was about right and the component was seen as very useful and very good. One user referred to it as ‘superb’ and ‘just what we want’.

Again the issue of the need to keep the information up-to-date was raised.

One user felt put off by the amount of text and felt that bullet points would be better, with the opportunity to click on the bullet points to get more information.
It would be useful to be able to link the encyclopaedia to the fungicide performance screen.

It was felt unnecessary to refer to 'Septoria nodorum' as 'blotch' as everyone knew it as 'Septoria nodorum'. The same was true for 'Septoria tritici' which was referred to as 'leaf blotch'.

The back button in the encyclopaedia should look more like the back button on a browser and the search facility should be on the control bar, not a button.

Those who rated the information as 'not detailed enough' wanted to see diagnosis for less common diseases, relative curative activities, kickbacks and protection periods. Also the products relating to control of a disease should be listed at the bottom of the disease control section.

It was suggested that links should be available to other sources of information such as HORIS and Internet sites.

3.5 Problems with the existing system

This section summarises the main problems identified with the existing system, many of them will have been raised in previous sections. Each problem has been given a unique number.

3.5.1 Farm navigation

Problem 1: Accessing different level of information not easy for users unless they were able to remember how to use the right hand mouse button

Problem 2: Selection of the second category on toolbar results in unexpected displays and a large number of tabs which is not useful

Action: TBD

Problem 3: Pull down menus not wide enough to view full text

Action: Increase the width of pull down menus in farm navigation system to accommodate full text.

Problem 4: Treatment display is not intuitive and will be filled up too quickly

Action: TBD

Problem 5: Occasionally zoom out to 100% doesn't work

Action: Check for zoom out to 100% intermittent bug on farm navigation system map display,
Problem 6: User lost highlighting on display when used pull down menu
Action: Ensure highlighting on farm navigation spreadsheet display isn't lost when user uses menus.

Problem 7: Users unsure of difference between 'treatment' and 'treatment product' on menu
Action: Change menu item names in farm navigation system to make distinction between 'treatment' and 'treatment product' clear.

Problem 8: Listing of disease levels is not consistent with disease observation dialog
Action: Use same numeric format for listing disease observations in farm navigation system as in disease observation dialog.

Problem 9: Right hand mouse click to get menu is not obvious to many users
Action: Farm navigation system should not rely on people using right hand mouse click to get easy access to farm information.

Problem 10: Users concerned about source of farm map
Action: Clarify method by which users will get farm map(s) into farm navigation system
Action: Help system to contain details of how users will get farm map(s) into farm navigation system

3.5.2. Fungicide Decision Module

3.5.2.1 Graphical spray plan display area

Problem 11: Confusion between treatment effect display and variability of yield/margin display
Problem 12: Not immediately obvious that treatment arrow relates to treatment effect
Action: Make treatment efficacy display the same colour as the treatment arrow (green not favoured by one user)

Problem 13: Misunderstanding of what exactly is meant by red/yellow risk areas
Action: Produce tool-tip' help to explain exactly what red/yellow risk areas mean

Problem 14: Users not sure what is in treatment on each date
Action: Produce 'tool-tip' to show what is in individual treatment (as planned)

Problem 15: Users not sure what date treatment took place (or is planned)
Action: The 'tool-tip' showing individual treatments should also show date of application

3.5.2.2 Date bar

Problem 16: Date bar units not clear
Action: Colour code months/years on date line to show changes between them (?)

Problem 17: Users want to use growth stages on date line
Action: Growth stage units to be available for date line (as planned)

Problem 75: User wanted date bar to be more like a ruler
Action: TBD
3.5.2.3 Spray indicator

Problem 18: Users not clear what date they are moving indicator to
Action: Produce 'pop-up' date display to appear as spray indicator is being moved along date line

Problem 19: Spray indicator hard to move/no feedback of movement
Action: Use standard feedback techniques (i.e. shadowing) to show spray indicator is selected and moving

Problem 20: Users unsure about effect of moving spray indicator into past
Action: If spray indicator is moved into past use pop-up display to indicate that such information cannot be saved. The user should be allowed to disable the pop-up.

Problem 76: The arrow to indicate a spray event is in the wrong place as it obscures the date.
Action: TBD

3.5.2.4 Spray plan dialog

Problem 21: Typing in date is tedious
Action: Use calendar input (as in weather module) in spray plan dialog as alternative method of inputting date.

Problem 22: Users unclear as to meaning of dose figures
Action: In spray plan dialog make the litres per hectare heading more prominent.
Problem 23: Display could usefully provide a 'number of days from spray to current date' heading to support task.

Action: Investigate possibility of providing an additional heading in the spray plan display to show number of days from past treatment dates to current date.

3.5.2.5 Tabbed area - Canopy Management Display

Problem 24: Leaf display is incomplete/confusing

Action: Plant images on canopy management tab to increase in size with season (as planned)

Action: Plant images on canopy management tab not to display 'ear' until appropriate time (as planned)

Action: Canopy management tab to display GLA figures under plant images. (as planned)

Action: Leaf number to be shown on LHS of display of canopy management tab (as planned)

Problem 25: User at York suggested degree of diseased tissue before the disease event on canopy management tab was excessive

Action: Query excessive degree of diseased tissue before the disease event on canopy management tab with model developers

3.5.2.6 Yield/margin display area

Problem 26: Margin is more important to users than yield

Problem 27: Margin has to show variability

Action: In yield variability area: use margin and variability as default display

Action: In yield variability area: Allow users to flip between margin/yield as required (or) have both margin and yield as displays side by side

Problem 28: Single figure in yield variability area display falsely indicates accuracy

Action: In yield variability area: use range of 1 standard deviation (?) instead of single figure
<table>
<thead>
<tr>
<th>Problem 29:</th>
<th>User needs to see more than 2 or 3 previous results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action:</td>
<td>In yield variability area: use 10 previous sprays as default (bottom ones drop off) (as planned)</td>
</tr>
<tr>
<td>Action:</td>
<td>In yield variability area: allow user to set number of sprays as preference</td>
</tr>
<tr>
<td>Problem 30:</td>
<td>Users want to know what data went into the yield/margin variability calculation</td>
</tr>
<tr>
<td>Action:</td>
<td>In yield variability area: pop-up help to show formula for calculating margin/yield and variability</td>
</tr>
<tr>
<td>Problem 77:</td>
<td>One user was not happy with the colour of the yield bar. They felt that green should be for leaves, brown is for wheat</td>
</tr>
<tr>
<td>Action:</td>
<td>Re-assess the colour of the yield and spray areas.</td>
</tr>
</tbody>
</table>

### 3.5.2.7 Inputs to models, Run model & Optimise buttons

<table>
<thead>
<tr>
<th>Problem 31:</th>
<th>Users had difficulty distinguishing between and understanding model buttons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action:</td>
<td>Re-name buttons on bottom RHS of WDM screen to: 'Settings'; 'Run'; 'Suggest treatments'.</td>
</tr>
</tbody>
</table>

### 3.5.2.8 Inputs to models dialog

<table>
<thead>
<tr>
<th>Problem 32:</th>
<th>Users need to know how much each variable will influence the precision of the model calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action:</td>
<td>Help (from inputs to model dialog and from disease observation dialog) has to make clear which are the most influential variables i.e those which greatly affect the output of the models, and those which are only used to 'fine tune' the output. This information should also be made available in the written documentation.</td>
</tr>
<tr>
<td>Problem 33:</td>
<td>Grain prices are not visible or editable at present.</td>
</tr>
<tr>
<td>Action:</td>
<td>Include grain price as editable field within 'input to model' dialog</td>
</tr>
</tbody>
</table>
Problem 34: If input fields are left blank users worry that they have to enter information for the model to run properly

Action: Ensure that all fields in the 'inputs to models' dialog are filled either by default values or by user or CMS derived inputs (as planned).

### 3.5.2.9 Running process model

Problem 35: Most users had to be reminded to use the 'run model' button after changes

Action: If final process model is as fast as current version then default to automatically running after changes on WDM screen (user can also change in preferences)

Problem 36: Users wanted to see effect of moving spray back to cover risk events

Action: Complete the integration of models and interface so that risks are eliminated by moving treatment dates to appropriate positions (as planned)

### 3.5.2.10 Running decision model

Problem 37: Not enough feedback of activity/time to complete run

Action: When decision model is running provide a status display with 'time to complete' feedback (as planned)

Problem 38: Users perception of acceptable time decision model should be running is very low

Action: Give feedback on expected time to complete decision model run (as planned)

Action: Allow users to stop decision model run at any point (as planned)

Action: Allow users to accept current state of decision model output (as planned)

Action: Ensure that users are given instructions on how to reduce the time the decision model takes to run within the help system.

Action: Find a way that users could integrate the long running time of the decision model into their daily routine and make this clear in the project advertising/documentation.
<table>
<thead>
<tr>
<th>Problem 39:</th>
<th>Users clicked twice on optimise button and got strange results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action:</td>
<td>Prevent system from accepting more than one call to the decision model at a time.</td>
</tr>
</tbody>
</table>

3.5.2.11 Optimise screen

<table>
<thead>
<tr>
<th>Problem 40:</th>
<th>Users tried to make changes to spray program within optimise screen and then run model again</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action:</td>
<td>Use non-editable format for display of spray contents within optimise screen.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Problem 41:</th>
<th>Users want easy method of viewing contents of treatments on optimise screen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action:</td>
<td>Colour code treatments to either a) show that treatment is a mix or b) indicate what the contents of the mix are. Possibly change icons to △⊙</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Problem 42:</th>
<th>Users did not find selecting option from optimise screen and exiting intuitive.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action:</td>
<td>Identify means of highlighting selected option on optimise screen</td>
</tr>
<tr>
<td>Action:</td>
<td>Provide shortcut to allow selection and exit in same action (e.g. double click)</td>
</tr>
<tr>
<td>Action:</td>
<td>Change name of OK button on optimise screen to make action more obvious e.g. 'Use selected program'</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Problem 43:</th>
<th>In optimise screen, users forgot which plans they'd already looked at and the details of those plans.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action:</td>
<td>To support users memory for plans by providing 'at a glance' display of spray contents in optimise screen.</td>
</tr>
<tr>
<td>Problem 44:</td>
<td>Users wanted to return to previous optimisation results</td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>Action:</td>
<td>Identify and produce mechanism whereby users can return to results of previous optimisation i.e. list of suggested treatments</td>
</tr>
<tr>
<td>Problem 45:</td>
<td>Users wanted to know whether the plans were significantly different from one another</td>
</tr>
<tr>
<td>Action:</td>
<td>Present results of optimisation in bands according to statistical significance of difference between them (method of banding needs defining)</td>
</tr>
<tr>
<td>Problem 46:</td>
<td>Second run of decision model produced a screen with identical plan icons but different plan contents. (?)</td>
</tr>
<tr>
<td>Action:</td>
<td>Check and resolve bug in optimise screen causing difference between spray plan representation &amp; contents. (?)</td>
</tr>
<tr>
<td>Problem 47:</td>
<td>Several users commented on use of Tilt. They felt too high a does and old fashioned product.</td>
</tr>
<tr>
<td>Action:</td>
<td>Check with model producers/agronomists that use of Tilt at suggested dose (optimise screen) is acceptable given limited product range.</td>
</tr>
<tr>
<td>Problem 48:</td>
<td>Some users wanted the model to provide a window for application and not a single date.</td>
</tr>
<tr>
<td>Action:</td>
<td>Investigate and document the possibility of providing users with a spray window and not a single spray date from the decision model.</td>
</tr>
<tr>
<td>Problem 49:</td>
<td>Margin figure is too precise, need to show variability.</td>
</tr>
<tr>
<td>Problem 50:</td>
<td>Margin information is more important than yield</td>
</tr>
<tr>
<td>Action:</td>
<td>In optimise screen yield variability area: use margin and variability as default display</td>
</tr>
<tr>
<td>Action:</td>
<td>In yield variability area of optimise screen: Allow users to flip between margin/yield as required (or) have both margin and yield as displays side by side</td>
</tr>
<tr>
<td>Action:</td>
<td>In yield variability area of optimise screen: Use single standard deviation figures as range rather than mean figure for margin/yield.</td>
</tr>
</tbody>
</table>
Problem 51: Users want to know what data went into the yield/margin variability calculation
Action: In yield variability area of optimise screen: pop-up help to show formula for calculating margin/yield & variability

Problem 78: Users want to see costs of application
Action: TBD

Problem 79: On the strategic screen the units did not have values
Action: Add values to strategic screen display

3.5.3 Disease Observations dialog

Problem 52: Users need help in identifying percentage levels of disease
Action: Context specific help on disease observations dialog should provide pictorial support for identifying percentage levels of disease. (as planned)

Problem 53: High, medium and low indicators should be linked to a percentage disease
Action: In disease observations dialog, detailed tab, the movement of the high/med/low indicator should be linked to the contents of the percentage box output.

3.5.4 Encyclopaedia - information and layout

Problem 54: Headings appear in both index and information portions of the encyclopaedia
Action: Integrate headings from index and information portions of the encyclopaedia such that each disease heading in the index breaks down further into lifecycle, control etc.

Problem 55: Users unable to find some diseases because they are listed under unfamiliar 'common' names.
Action: Ensure that name provided in index and at the top of the information page of the encyclopaedia is the one most often used by farmers and consultants. In particular Septoria tritici and Septoria nodorum should be labelled as such and not by their common names.
Problem 56: Users unable to find encyclopaedic information easily when it is on a second page, they are not very familiar with the use of scroll bars.

Action: Encyclopaedia pages should, where possible, not exceed one page in length.

Action: Where possible reduce information in encyclopaedia to bullet points for clarity.

Problem 57: Users felt that there wasn't enough linking of information.

Problem 58: Method for accessing picture information is not standard.

Action: Complete integration of encyclopaedia into Browser format so that text and picture links can be properly checked for number and access standards.

3.5.6 Browser

Problem 59: Back and page layout icons in the browser confused some users.

Action: Use icons and icon positions from Explorer/Netscape to denote back/forward and layout type in Browser.

Problem 60: Not clear how many tabs users can save or how tabs differ from normal bookmarks.

Action: Ensure that Help contains information about the use of tabs in the Browser, their function, the number a user can store, their distinction from bookmarks.

Problem 61: Users wanted to know if the browser could pick up their existing bookmarks.

Action: Query as to whether the Browser could make use of users existing bookmarks.
### 3.5.7 HGCA Varieties information

**Problem 62:** Users need to be able to choose whether to sort in ascending or descending order and this may be different for each column.

**Action:** In the varieties information screen provide users with a quick means of changing the direction (ascending or descending) of the sort.

**Problem 63:** Users did not know that headings were buttons

**Action:** Create tool-tip to explain use of column headings in varieties display

**Problem 64:** Users did not realise that clicking on the buttons sorted the column even with the written instruction on the screen.

**Action:** Increase prominence and visibility of screen instruction (click to sort) in HGCA varieties screen (?)

**Problem 65:** Users want to be able to sort on a number of characteristics at the same time i.e. standing power, yield and resistance

**Action:** Restructure variety screen so that users can sort on a number of characteristics at the same time (in different directions e.g., highest standing power, lowest susceptibility)

**Problem 66:** Users liked tidiness of screen but may need to see different headings at same time

**Action:** Look at possibility of restructuring variety screen so that users can view their own choice of headings.

**Problem 67:** Users need to see significance of difference between varieties information

**Action:** Variety display will have to show the statistical significance of differences between varieties on characteristics.
3.5.8 Strategic screen

Problem 68: As in tactical screen margin is more important than yield
Action: In yield variability area: use margin and variability as default display
Action: In yield variability area: Allow users to flip between margin/yield as required (or) have both margin and yield as displays side by side

Problem 69: Single figure in yield variability area display falsely indicates accuracy
Action: In yield variability area: use range of 1 stand. deviation (?) instead of single figure

Problem 70: Some indication of what products are in stock would be useful on the chemical summary tab.
Action: Investigate possibility of putting a stock column in the chemical summary tab (e.g., previous design idea) of strategic screen.

Problem 71: Distributors and farming co-ops may want to summarise across farms on chemical summary tab
Action: Explore means by which users could block on farms to produce a group chemical summary report in strategic screen.

3.5.9 General display

Problem 72: Icon for encyclopaedia not intuitive
Action: Icon for encyclopaedia: Tidy up/make more intuitive

Problem 73: Icon for HGCA variety information not intuitive
Action: Icon for HGCA variety information: Tidy up/make more intuitive
Problem 74: Having got used to accessing information about fields by using the RH mouse menu in the navigation module, users expected to be able to access the same information from within WDM.

Action: The ability to view field information on the farm data screen using the RH. mouse button could be extended over the whole system.
4.0 Discussion

In summary the results of the laboratory trials were very encouraging, all users found some aspect of the system which made DESSAC useful to themselves or to their organisations. There have been few usability trials in HUSAT's experience which have generated such glowing remarks. There were a number of problems identified which should be addressed prior to release but most of these were cosmetic or related to technical problems. That is not to say they should not be treated seriously, or that they will not cause some headaches for those responsible for addressing them. The results of the trials however make it clear that the functionality provided by DESSAC meets its objective of supporting the user in making fungicide decisions. The trials indicate that the three major hurdles for widespread acceptance are likely to be: the scientific validation of the models, the reliable updating of the information within the system; and the pricing of the product.
APPENDIX I:
Presentation of Uncertainty Paper


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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There is increasing interest in the potential of Decision Support Systems (DSS) in agriculture. DSS are usually based on simulation models with which a degree of uncertainty is always associated. In response to the practical problem of how to present this uncertainty to non-technical users a literature review was undertaken. The maturity of this technology in other industrial sectors led to the expectation that answers already existed. Results so far suggest that this belief was unfounded. This paper is a first attempt to collate the answers which do exist and some general guidelines for presentation are given.

Introduction

This paper stems from a very specific practical problem, the need to produce a design solution to an interface requirement for an agricultural decision support system. DESSAC (Decision Support Systems for Arable Crops) is a MAFF Link-funded project which has as part of its remit the development of a decision support system (DSS) for winter wheat fungicide use.

A decision support tool (DSS) can be defined as a tool which helps the user to make better decisions by providing access to a model or rule based representation of the decision area and to supporting information. There is an increasing interest in the potential of these tools in the agricultural and horticultural industries. Agricultural DSS, in common with any system attempting to describe and predict natural processes, are not capable of giving definitive answers. The emphasis is on support and not decision making. Agricultural DSS contain one or more simulation models which approximate the interactions between biological systems. As these models are only estimates there is always a degree of uncertainty associated with their output, (often shown as a probability distribution). A major requirement at the interface is the expression of this uncertainty as well as the general estimate of risk.

The DESSAC system needs to display a variety of solutions to a spray plan problem so that the user can identify the best fit solution and the differences (or lack of these) between the risk levels associated with them. Farm-based users need to know what the worst, best and most likely outcomes, and the spread between them, might be, so that they can make realistic comparative decisions. What exactly is the problem in displaying something that the statistical sciences have been expressing for a long time? Firstly, there is the non-technical background of the target audience. The DESSAC project is working on the assumption that the user
population will be computer literate but have little familiarity with statistics or the
nature of modelling uncertainty. Previous work in the area suggests that few
agricultural users are aware of the limitations of models; there is a tendency to either
accept the output of the tool as 100% accurate or to view it with an extreme degree of
prejudice. Good communication of uncertainty is always critical to good decision
making (Cleaves, 1995) but obviously more so under these circumstances.

Secondly there is the underlying assumption that these systems should also
improve the general level of decision making. The reason that agricultural DSS are
funded is the urgent need to reduce, or to target more effectively, the use of agro-
chemicals in the UK. The human interface to the DSS therefore has three jobs to do:
It has:
• to guide the user in the direction of better decision making,
• to present decision supportive information to the user, and
• to make best use of human capabilities.
It has to do this in the context of a non-technical user group, working with a complex
problem in real time.

As this is a problem common to all decision support systems, an early literature
review was conducted in the strong belief that answers would already exist. Six
months later few solutions have been found. This paper is a first attempt to bring
together the answers which do exist and to place them in a context which is
meaningful for the developers of decision support systems.

Types of uncertainty

DSS are based either on simulation models, or on rules extracted from domain
experts, or on a mixture of the two, and their answers to the questions posed by the
user will always have a degree of uncertainty around them. But what exactly do we
mean by uncertainty in this context? What types of uncertainty have been identified?
Finding an appropriate categorisation for uncertainty should make it easier to group
design solutions in a way which is useful for DSS developers.

Krause and Clarke (1993) provide a branching classification system in which
types of uncertainty are first divided according to whether they relate to a single
proposition or to a group of propositions; then whether they arise from ignorance or
from conflict and finally into 8 sub categories (op cit. p.7). The critical ones for this
discussion relate to the unary set and are: Indeterminate Knowledge (vagueness);
Partial Knowledge (confidence); Equivocation; Ambiguity; and Anomaly (error).

<table>
<thead>
<tr>
<th>Table 1: Uncertainty types within Information categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncertainty type</td>
</tr>
<tr>
<td>Info. category</td>
</tr>
<tr>
<td>Factual non-inferential</td>
</tr>
<tr>
<td>Instructive (basic 'what if')</td>
</tr>
<tr>
<td>Predictive (comp. what if)</td>
</tr>
<tr>
<td>Factual inferential</td>
</tr>
<tr>
<td>Causal inferential</td>
</tr>
</tbody>
</table>

D
A DSS provides the user with many types of information, e.g. the set identified by Brookes (1985). Each type of information may bring with it its own form of uncertainty. Table 1 above lists Brookes' information retrieval categories and suggests the types of uncertainty, as defined by Krause and Clarke, to be found within them.

The table shows that different types of uncertainty are present in the various information categories and that there is a further division, between input and method: uncertainty within a DSS relating either to the data fed into the system, and/or to the method (models or rules) used to generate the answers to decision enquiries (Arinze, 1989).

In the case of the first two of Brookes' categories, the mechanisms for generating an answer are purely mechanical and based on very simple and very complete algorithms. No uncertainty is generated by mechanisms (models or rules) in these cases, the only possible source of uncertainty is that associated with the data fed into them. As all data is prey to anomaly (input error) and much real data contains missing values (indeterminate knowledge) it must be assumed that these types of uncertainty are always be associated with inputs.

Where data is generated (i.e. by a model) rather than input there will be uncertainty associated with the mechanism used for the generation (predictive information). In the case of agricultural systems any prediction of weather conditions or disease progress will be prone to 'partial knowledge' uncertainty because it is impossible to produce an accurate simulation of these complex and chaotic systems. Any other use of models or rules is prone to the same type of uncertainty. On the output side these systems may produce ambiguous results where it is not clear which of a number of outcomes is preferable. Rule bases are also prone to equivocation, where two or more rule sets are equally applicable.

Another level of categorisation which is particularly relevant to uncertainty in DSS is the type of data being displayed i.e. whether it is nominal, ordinal, interval or ratio based numeric data or whether it is textual. Expert systems, based on rules extracted from experts, may produce numeric or textual data but the numeric data is likely to be an expression of an expert opinion. Model based systems on the other hand produce numeric uncertainty based on the application of equations to numeric inputs (inputs which may of course be based on non-numeric judgements).

Display solutions

Many papers describe the performance of graphical vs. tabular vs. textual displays for interval and ratio type numeric data often with conflicting findings: others suggest that a mix of tabular and graphical displays produce the best performance (e.g. Bennet, 1992). In general the literature seems to suggest a graphical format is the easiest to interpret, even for small data sets (Melody Carswell, 1997) and given the additional difficulties surrounding uncertainty a graphical format may be considered to be the better approach. However, the influence of the graphical display is also found to be highly dependent on the type of task it is intended to support. The right graphical display is thus needed to express specific task uncertainties.

In the only experiment of its type this survey was able to locate, Ibrekk and Morgan (1987) look specifically at the problem of graphically representing uncertainty to non-technical users. Two types of users (non-technical and technically aware) were presented with 9 graphical displays of the same data with and without instruction. The displays were: a point estimate with error bar; six displays of probability density (discretised display, pie chart, conventional, mirror image display, horizontal bars shaded to display density using dots or vertical lines.); a Tukey box plot; and a cumulative distribution function. Six forms of the probability density display were used because formally equivalent representations are not often psychologically equivalent. Subjects were asked to make judgements about realistic
events such as the depth of predicted snowfall and flood. They found that the performance of a display depended on the information that the subject was trying to extract, and concluded that displays that explicitly show the information people need show the best performance. Pie chart displays were found to be potentially misleading and subjects displayed a tendency to select the mode rather than the mean unless the mean was explicitly marked. Where subjects were asked to make judgements about probability intervals in displays that did not forcefully communicate a sense of probability density, there was a tendency for them to use a linear proportion strategy equivalent to an assumption of a uniform probability density. Explanations had little effect on performance although there was evidence that subjects were trying to use them. Another finding was that there was little difference between the performances of the technical and non-technical groups and suggesting that a 'rusty' knowledge of statistics, or a graduate degree, will not necessarily improve performance. Designs which support non-technical users will therefore be equally valuable to the technically literate.

The alternative to graphical or tabular representations of uncertainty are textual/verbal representations. Budescu and Wallsten (1995) investigated information processing, choice behaviour and decision quality when subjective uncertainty was expressed linguistically or numerically. They identified two further categorisations of uncertainty, 'precise' and 'vague'. Uncertainty is precise if it depends on external, quantified random variation; and vague if it depends on internal sources related to lack of knowledge or judgements about the nature of the database (op. cit.) These distinctions map well onto Brookes information categories. Precise uncertainty can be linked to the first three categories, vague uncertainty with the last two because they relate very much to internal, user based uncertainty. In a later experiment Olson and Budescu (1997) found that verbal representations outperform numeric ones when the nature of the underlying uncertainty is also vague. The best mode of communication they suggest, is the one which most clearly matches the nature of the event and the source of its underlying uncertainty.

Summary

While there is insufficient room in this short paper to expand on, or even describe, all of the data gathered in this exercise, it is possible to make broad recommendations. It would appear that there are 3 key issues which impact on the form of representation for displaying uncertainty:

- the type of uncertainty being displayed (e.g. Krause's categories);
- the type of data being displayed (e.g. numeric, textual, precise or vague); and
- the users requirement for information to support the task (mean, mode, etc.).

In the latter case users may, or may not, need to see the reasoning behind the data. Tufte (1997) argues quite forcibly that they do, Ackoff (1967) that they don't. In the agricultural domain it seems likely that many farmers will not want to see the reasoning behind the data whereas most agronomy consultants and the more technically minded farmers will. The answer seems to be user dependent, requiring a layered interface approach.

The literature surveyed to date would seem to suggest the use of graphics as a first choice for representing numeric data of the 'precise type' i.e. relating to factual, instructive and predictive information; with tabular representation providing additional support. Where the data may be either numeric or textual and the type of uncertainty is 'vague' i.e. factual inferential and causal inferential information, then textual representation is to be preferred.

The results of Ibrekk and Morgans experiment suggest that within graphical display types mirror image displays and the shaded bar displays of probability density are the best for communicating the ranges that variables assume, and box plots or simple error bars are the best way of communicating means. It may be the case however that
explicitly marking the mean on the probability density display would produce the optimal solution for mean and range.

Conclusion

The title of this paper refers to the 'state of the art' in the representation of uncertainty in decision support systems and this paper has made a first attempt to define it. However while there is a great deal of work to which this paper has not referred given the limited space, the tragedy is that most of it is microscopic in scope. Published work deals with human limitations in relation to different display mechanisms, to the nature of uncertainty, to the differences between expert and non-expert users and to many other issues surrounding the problem. Very little is directly relevant to the designer of decision support tools. Indeed this review has made it apparent that not much has changed since the publication of Morgan and Henrion's book in 1990 where they concluded that: "for the most part the absence of empirical studies of the relative virtues of alternative displays means that the choice for displays remains largely a matter of personal judgement" (op. cit. p. 220). A great deal more targeted research is required if developers of decision support tools are to be given the practical guidelines they need.

Acknowledgements

The author wishes to thank Loughborough University; the DESSAC project, MAFF and HGCA for funding; Murray Sinclair; David Parsons of Silsoe Research Institute; and the many leads and pointers provided by Email contacts and colleagues to their own and others work in this area.

References

Agmodels survey

Initial call for UK DSS

Dear Agmodellers
I'm trying to create a list of decision support tools which are, or could be, available to UK farmers and growers. I would be grateful to anyone who can tell me about those they've come across. (If such a list exists already I would be even more grateful for knowledge of its whereabouts!) If responses are sent to me directly (to avoid clogging the discussion group) I will compile the list and post it to everyone.

I am also interested learning about US, Australian or other countries DSS's which could theoretically be employed in the UK.
APPENDIX J:
HORIS User Requirements Survey


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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HORIS

User Information Requirements
Results of initial survey

December 1996

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INTRODUCTION
The purpose of this document is to describe the results of the recent survey of brassica growers and their consultants into requirements for computer based encyclopaedic information. Encyclopaedic information is taken to be information which is not derived dynamically from other software but which may be static (need updating only once or twice a year) or dynamic (regularly updated).

This report describes the methods used to identify user requirements to date, the results of the surveys, conclusions and future methods to be adopted.

METHOD
Two methods have been used to date to elicit requirements from potential users of the brassica based information system, postal questionnaire and workshop/focus group. Postal surveys make it possible to reach a large number of people in a short amount of time and to get quantifiable answers to simple questions. Focus groups/workshops and, where small groups of users come together to discuss their needs, permit detailed discussion of particular topics and therefore provide richer data for the requirements analysis. The two methods are described below in more detail.

Postal survey
Two hundred and fifty questionnaires were sent out, in early November, to a mix of brassica growers and consultants. The questionnaire, a copy of which can be found in the appendices, asked the following questions.

- Location of enterprise.
  Respondents were asked where in the UK they farmed or based their consultancy practice. This data was required for checking that the results were not biased towards an unrepresentative area.

- Size of enterprise (hectares farmed or consulted on)

- Number of hectares devoted to brassica production
  In addition to checking that the survey produced a representative range of farm/consultancy sizes, this information was required for identifying whether the respondents answers to the other questions were a function of the size of enterprise or the area devoted to brassicas.

- Computer capability
  Respondents were asked if their computers, if they had one, met the minimum or recommended requirements for MORIS. This information was required to determine what the potential market might be for the HORIS product when released late in 1997.

- Brassica crops grown
  Respondents were asked to indicate which of the following crops they grew or advised on: sprouts, cabbage, cauliflower, calabrese, and swede, in order to get a feel for the spread of interest in the various brassicas.

- Information required
  Respondents were asked to indicate which of the types of information, shown in table 1, they thought would be either an essential or interesting part of a brassica
information system. Space was left on the following page for additional categories to be introduced by the respondents.

Table 1: Information which respondents were asked to select essential and interesting categories from.

<table>
<thead>
<tr>
<th>Information types</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pests - Identification</td>
<td></td>
</tr>
<tr>
<td>Pests - Damage caused</td>
<td></td>
</tr>
<tr>
<td>Pests - Control</td>
<td></td>
</tr>
<tr>
<td>Diseases - Identification</td>
<td></td>
</tr>
<tr>
<td>Diseases - Damage caused</td>
<td></td>
</tr>
<tr>
<td>Diseases - Control</td>
<td></td>
</tr>
<tr>
<td>Nutrition - Identification of problems</td>
<td></td>
</tr>
<tr>
<td>Nutrition - Rates and timings</td>
<td></td>
</tr>
<tr>
<td>Weeds - Identification</td>
<td></td>
</tr>
<tr>
<td>Weeds - Control</td>
<td></td>
</tr>
<tr>
<td>Chemicals - Active ingredients</td>
<td></td>
</tr>
<tr>
<td>Chemicals - Dose, timing</td>
<td></td>
</tr>
<tr>
<td>Chemicals - Safety aspects</td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td></td>
</tr>
<tr>
<td>Harvest (maturity prediction)</td>
<td></td>
</tr>
<tr>
<td>Spacing</td>
<td></td>
</tr>
<tr>
<td>Varieties</td>
<td></td>
</tr>
<tr>
<td>Rotation</td>
<td></td>
</tr>
<tr>
<td>Seed sources</td>
<td></td>
</tr>
<tr>
<td>Crop scheduling</td>
<td></td>
</tr>
<tr>
<td>Cultivation</td>
<td></td>
</tr>
<tr>
<td>HDC reports</td>
<td></td>
</tr>
</tbody>
</table>

Workshops
Workshops comprising 6-8 potential users were planned for late November. A form was sent out with the postal questionnaire asking people if they would like to attend one of 4 potential sessions on the 18th and 19th September. The form of the sessions was planned to be:

- Introduction to the project
- Feedback from the questionnaire results
  Showing the users the main results from the questionnaire as a focus for discussion.
- 'Brainstorm' on requirements for most popular information categories
  i.e. what specific questions are the users looking to answer under the information headings; what sources of information so they currently use.
- Review of MORIS
  Walkthrough the system explaining the concepts and content and asking for feedback on the information content and format in relation to the future brassica system. Users then to be given the chance to 'play' with the system themselves and to make additional comments.
- Summary of requirements
  Bringing together all the main points of the session for the participants to agree on and prioritise.
All participants to be invited to participate in later trials and to be given a demonstration copy of MORIS to take away with them.

RESULTS

Postal survey
To date 66 responses have been collated (although several more have been returned since the data analysis began), which equates to a return rate of 27.5%. A 20% return rate is average for a postal survey. Of the total 43 were farmers and 23 were consultants.

Location of enterprise.
The spread of respondents is broad and is represented in figure 1 below.

![Figure 1: Location of respondents enterprises](image)

The key brassica growing areas are well represented but there is a reasonable spread across the rest of the country.

Size of enterprise
The areas farmed by the grower respondents are shown in table 2 below.

<table>
<thead>
<tr>
<th>Hectares</th>
<th>Area farmed</th>
<th>Brassica area</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-100</td>
<td>12</td>
<td>27</td>
</tr>
<tr>
<td>101-200</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>201-400</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>401-600</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>601-800</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>801-1200</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>1201+</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
The sample contains a broad range of farm sizes, although most of the sample are concentrated in the 200 hectares or less range there are over 30% who farm more than 400 hectares.

Machine capability

Table 3: Number of respondents owing machines with minimum or recommended requirements for MORIS

<table>
<thead>
<tr>
<th></th>
<th>Growers</th>
<th>Advisers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(43 responses)</td>
<td>(23 responses)</td>
</tr>
<tr>
<td>Recommended</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>Minimum</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Possibly less than minimum</td>
<td>16</td>
<td>3</td>
</tr>
</tbody>
</table>

Most of the consultants own systems with the recommended requirements (20 out of 23 respondents), 2 of those who don't do not advise on the brassica crops of interest to the survey. Over 50% of the grower respondents own recommended machines (24 out of 43 respondents) and a further 3 own machines with the minimum requirements.

Farm size and computer ownership - those with recommended systems

Table 4: Farm size and number of recommended systems

<table>
<thead>
<tr>
<th>Hectares</th>
<th>Farm numbers</th>
<th>No. with recommended systems</th>
<th>% in category owning recommended systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-100</td>
<td>12</td>
<td>4</td>
<td>33.33</td>
</tr>
<tr>
<td>101-200</td>
<td>9</td>
<td>4</td>
<td>44.44</td>
</tr>
<tr>
<td>201-400</td>
<td>7</td>
<td>7</td>
<td>100.00</td>
</tr>
<tr>
<td>401-600</td>
<td>6</td>
<td>2</td>
<td>33.33</td>
</tr>
<tr>
<td>601-800</td>
<td>3</td>
<td>1</td>
<td>33.33</td>
</tr>
<tr>
<td>801-1200</td>
<td>4</td>
<td>3</td>
<td>75.00</td>
</tr>
<tr>
<td>1201+</td>
<td>2</td>
<td>2</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Table 4 shows the relationship between farm size and the distribution of recommended computers. Farms between 200 and 400 ha and those over 800 ha seem to be the most likely to own the recommended hardware. This is a similar pattern to that seen in the arable sector.

Brassica crops grown/advised on

Table 5: Types of brassica grown or advised on by respondents

<table>
<thead>
<tr>
<th></th>
<th>Growers</th>
<th>Advisers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprouts</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Cabbage</td>
<td>26</td>
<td>12</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>26</td>
<td>10</td>
</tr>
<tr>
<td>Calabrese</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>Swede</td>
<td>8</td>
<td>11</td>
</tr>
</tbody>
</table>
Cabbage and cauliflower appear to be the most commonly grown brassicas although sprouts and swede are produced by over 30% of the growers. The number growing swede is less than 20%. The consultants appear to advise on all of the crops in roughly equal proportions.

Sample used for information requirements

While all of the sample was used to look at computer requirements and distribution of farms the numbers used to determine the information requirements were restricted to those who grow the brassica crops specifically mentioned in the questionnaire. This reduced the numbers to 41 growers and 18 consultants, a total information set of 59.

Information requirements

Table 6 shows the information requirements in order of their importance i.e. ranked according to the number of growers who felt the information was essential.

<table>
<thead>
<tr>
<th>Information</th>
<th>Growers Essential</th>
<th>Growers Interesting</th>
<th>Consultants Essential</th>
<th>Consultants Interesting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Chemicals - Dose, timing</td>
<td>34</td>
<td>82.93</td>
<td>4</td>
<td>9.76</td>
</tr>
<tr>
<td>Pests - Control</td>
<td>33</td>
<td>80.49</td>
<td>4</td>
<td>9.76</td>
</tr>
<tr>
<td>Diseases - Control</td>
<td>32</td>
<td>78.05</td>
<td>5</td>
<td>12.20</td>
</tr>
<tr>
<td>Nutrition - Rates and timings</td>
<td>31</td>
<td>75.61</td>
<td>7</td>
<td>17.07</td>
</tr>
<tr>
<td>Chemicals - Safety aspects</td>
<td>29</td>
<td>70.73</td>
<td>8</td>
<td>19.51</td>
</tr>
<tr>
<td>Chemicals - Active ingredients</td>
<td>28</td>
<td>68.29</td>
<td>9</td>
<td>21.95</td>
</tr>
<tr>
<td>Diseases - Identification</td>
<td>27</td>
<td>65.85</td>
<td>11</td>
<td>26.83</td>
</tr>
<tr>
<td>Weeds - Control</td>
<td>27</td>
<td>65.85</td>
<td>11</td>
<td>26.83</td>
</tr>
<tr>
<td>Pests - Identification</td>
<td>26</td>
<td>63.41</td>
<td>11</td>
<td>26.83</td>
</tr>
<tr>
<td>Nutrition - Id. of problems</td>
<td>26</td>
<td>63.41</td>
<td>10</td>
<td>24.39</td>
</tr>
<tr>
<td>Varieties</td>
<td>24</td>
<td>58.54</td>
<td>12</td>
<td>29.27</td>
</tr>
<tr>
<td>Spacing</td>
<td>21</td>
<td>51.22</td>
<td>14</td>
<td>34.15</td>
</tr>
<tr>
<td>Irrigation</td>
<td>20</td>
<td>48.78</td>
<td>15</td>
<td>36.59</td>
</tr>
<tr>
<td>Harvest (maturity prediction)</td>
<td>20</td>
<td>48.78</td>
<td>13</td>
<td>31.71</td>
</tr>
<tr>
<td>Pests - Damage caused</td>
<td>19</td>
<td>46.34</td>
<td>15</td>
<td>36.59</td>
</tr>
<tr>
<td>Diseases - Damage caused</td>
<td>19</td>
<td>46.34</td>
<td>14</td>
<td>34.15</td>
</tr>
<tr>
<td>Weeds - Identification</td>
<td>19</td>
<td>46.34</td>
<td>16</td>
<td>39.02</td>
</tr>
<tr>
<td>Storage</td>
<td>16</td>
<td>39.02</td>
<td>15</td>
<td>36.59</td>
</tr>
<tr>
<td>Crop scheduling</td>
<td>14</td>
<td>34.15</td>
<td>16</td>
<td>39.02</td>
</tr>
<tr>
<td>HDC reports</td>
<td>11</td>
<td>26.83</td>
<td>21</td>
<td>51.22</td>
</tr>
<tr>
<td>Seed sources</td>
<td>10</td>
<td>24.39</td>
<td>18</td>
<td>43.90</td>
</tr>
<tr>
<td>Rotation</td>
<td>9</td>
<td>21.95</td>
<td>22</td>
<td>53.66</td>
</tr>
<tr>
<td>Cultivation</td>
<td>7</td>
<td>17.07</td>
<td>24</td>
<td>58.54</td>
</tr>
</tbody>
</table>

The most popular choices appear to be concerned with the control of problems and the use of chemicals. Identification of pest, disease and nutritional problems also appears to be seen as essential by a high percentage of users. Growers and consultants produced similar responses although consultants were more interested in information about crop scheduling than growers and less interested in identification of problems and nutritional information.
The response to the request for participants was much less than hoped for and much less than previously experienced in similar exercises with the result that only two very small sessions were eventually held on the 19th November at HRI Kirton. Four people participated in the morning session and three people in the afternoon session. There was a remarkable uniformity of views considering that the groups were a mix of growers (5) and consultants (2). The results of the discussions are summarised below under the information headings which emerged from the day.

Control of pests, diseases, weeds and nutritional deficiencies
Both groups seemed to feel that the requirements for all problems areas were similar enough to group them together. Information about the control of problems appeared to be the major requirements for all participants.

Main points
Information on chemicals for control of pests, diseases, nutrition and weeds is the most critical requirement. The type of information provided by MORIS was thought to very good. They would also like any other information about good practice; residues; information on rates; and simple summaries of research on the topic.

They felt that linking chemical details with information on ICMS/IPM environmental impact would be very useful.

Information on legislation (chemical and fertiliser related) in plain English.

Specific items mentioned
- New chemicals
- Which one's can I use (Tesco's). Which actives are listed for supermarket - what are alternatives.
- Which active is specific for that pest
- What chemicals have been shown to cure the problem
- Plus information on doses, harvest interval, active ingredient, which crops it is suitable for.
- Off label recommendations in printable format
- Full or off label approval
- COSHH information, protective clothing.
- Needs to be accurate and up to date.
- Good search facility required - by problem, actives, labels, crop etc.
- Chemical details - what is best for specific problem, duration, toxicity, range, harvest interval, mode of action.
- More detail on how chemicals work in a graphical, easy to read format.
- Information on possible cheaper, easier methods
- They would like to be able to personalise the information for their own needs and to be able to pull out the information to use as justification for retailers.
- Summarise ADAS fertiliser book - timings, soil & liquid rates
- Would like to access previously stored information on nutrition
- Legislation in plain English - fertilisers, buffer zones, chemicals
Identification of pests, diseases, weeds and nutritional deficiencies

After control, identification of problem areas seemed to be the next most essential area in which support is required. Information on all brassica pests, diseases, nutritional problems was felt to be necessary.

Specific items mentioned
- They would like photographs to aid identification of pests, diseases, weeds and nutritional problems. The photos should include the effects of growth stage. They seemed to feel that although a pocket booklet to take down the field was a good idea that bringing a sample back to the office was not a problem.
- A set of small pictures could be used as a key to aid identification.
- Pictures should be in small version on screen and capable of being expanded when selected.
- Pictures should show variation in colour especially for aphids.
- Weeds pictures should show cotyledon stage and full grown plant.
- Pictures of micro nutrition deficiencies
- Short simple descriptions, like the ones on the old ADAS cards should accompany the pictures.

- Information on life-cycle would be useful, especially pointing out the best time to spray, thresholds and the effects on breeding/or life-cycle of different variables.
- Calendar/weather based information on when should be going out to look for problems and critical things to look for

- Information and links to details about solutions (chemical and nutrient) should also be included in this section.
- Access to ADAS/HRI recommendations for nutrition would be useful.
- Information on fertilisers: what types exist, availability, sources.
- Detailed information on the effect of residual N - rain/etc....
- Detail on scientific understanding of the variables that effect N uptake

- One person felt that it would be useful to have information on the effects of Ph solubility
- Where to send samples - a yellow pages of who to contact.

Variety information

Information on varieties was felt to be useful by most of the participants.

Specific items mentioned
- Maturity
- Where to source seeds
- Yield potential
- Start - finish (season)
- Resistance - pests, disease, weather
- Quality
- Basically NIAB information plus more e.g. 1 year results on new varieties, new products from seed C&S + description

- Tools for helping user schedule and create continuity programs using this variety information
- Good search tool for this information is critical - it will be needed to help the users pick varieties suitable to specific needs.

Structure of system
A number of comments on the structure of the system were collated from the MORIS walkthrough. The participants thought the system should have a:
- simple and easy to access structure;
- structure which avoids the need to scroll through a lot of information;
- most detailed information at lowest level;
- the crop name as a good top level.

Miscellaneous items
A number of other points were raised during the day:
- New and scientific information would be most useful
- Basic crop husbandry information is not useful, except perhaps for colleges.
- Yearly updates would be acceptable although some things may need more regular updating e.g. SOCA's
- Scientific information should be collated and summarised. One line per paper describing actual practical implications of results would be a good top level with any other detail either hidden in lower layer or simply referenced.
- The cost and funding of the product was felt to be critical, they felt it would need to be pretty cheap to encourage use and that some central funding source should be investigated (HDC? advertising?)
- The real value of such a system would be in any 'add-on' tools that made it easy to calculate chemical requirements etc. i.e. decision support tools.
- A yellow pages of sources of information, chemicals, fertilisers etc. would be very useful.
- Basic horticultural statistics would be useful.

CONCLUSIONS
The information requirements for the HORIS system appear to be quite straightforward; both the postal survey and the workshops agree that control and identification of brassica problems are the key types of information the system should provide, with the addition of information on varieties. Information on these topics should come from established information sources but be given added value by supplementing with good practice tips and the summarised results of scientific research. The development of a 'yellow pages' of contacts would be considered very useful by most users. In the light of these clear requirements it is recommended that information is collated on these topics as a priority.

The control information provided by MORIS was considered to be quite appropriate for the purpose but users wanted photographs to be the primary method of identification within the brassica system. They also felt that the brassica system
should be more structured with the most detailed information stored at the lowest level. Information could be stored according to crop but users will want to search on more than one crop or topic.

Further workshops may be conducted in January when the need for additional information from the users is established.
APPENDIX K:
HORIS Evaluation Workshops Report


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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HORIS
Report on Prototype Evaluation
August 1997

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HUSAT Research Institute
Loughborough University
The Elms, Elms Grove
Loughborough, Leics LE11 1RG
1.0 INTRODUCTION
The purpose of this document is to describe the results of the evaluation of the prototype HORIS system workshops during June and July of 1997.

The aim of the HORIS project is to bring together the results of current research knowledge and best practice into a single information resource. Brassica crops were selected as the starting point for this exercise and the project is committed to producing a commercially available software package containing brassica related information in September 1997. The package 'Folio ViewsTm' was chosen as the container for the brassica information as its value had already been demonstrated in MORIS, an information system for the arable sector (Morley, 1996).

As part of a user centred design methodology the project identified the information, and information presentation, requirements for brassica growers (Parker, 1997) during its first few months. The next phase concerned the collation of information from a wide range of textual and human sources. This activity initially focused on the cabbage crop, as there was little difference between its information requirements and the other brassicas and it therefore provided a valuable template. The majority of the information on cabbages having been collated and incorporated into Folio Views the next stage in the design process was to evaluate the prototype software.

This report describes the method used in the evaluation, the results of this method, conclusions, and recommendations for amendments to the HORIS system.
2.0 METHOD
The method used to evaluate the prototype HORIS software with potential users of this brassica based information system were evaluation workshops. This method is described below in more detail.

2.1 Workshop
Seven 'workshop' sessions were planned over a period of 4 days (23rd and 24th June and 28th and 30th of July 1997). A representative range of users were sent a letter of invitation to attend one of the sessions, each session being set aside for one 'type' of user group i.e. grower or consultant. The initial plan was for at least 2 each of grower, consultant and seed merchant groups, each containing 7 or 8 participants. This number of participants per session was considered optimum to balance the requirement for maximum exposure and the need to ensure that each person felt able to participate fully.

The primary aim of the workshops was to gain feedback on the information within HORIS, and on its presentation; to check the projects interpretation of the initial user requirements and the design decisions taken. A secondary aim of the workshops was to publicise the development of the software and to gain some measure of its likely uptake.

Each of the sessions was designed to last 2.5 hours with a lunch period of 1 hour between the morning and afternoon slots. The timetable was as follows:

<table>
<thead>
<tr>
<th>Topic</th>
<th>Content</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Overview of the project, its aims, partners, the structure of the software, the purpose of the workshop and its timetabling. (see Appendix A for overheads)</td>
<td>10 mins</td>
</tr>
<tr>
<td>Explanation of software</td>
<td>Overview of the Folio views software - how to conduct searches, use of 'contents', hot links, backtrack and trail. Users split into groups between 3 machines. Identification of users previous related computing experience.</td>
<td>10 mins</td>
</tr>
<tr>
<td>Tasks</td>
<td>Task directed use of HORIS. Users asked to find the answers to 20 questions (see Appendix C), to ensure that they become familiar with the informational layout of the system and with the methods of finding information. Each section of the 'Cabbage Book' available for the workshop is represented within the questions.</td>
<td>45 mins</td>
</tr>
<tr>
<td>Coffee</td>
<td></td>
<td>10 mins</td>
</tr>
<tr>
<td>Free 'play'</td>
<td>Users encouraged to use the system to answer questions they would normally be interested in answering and to look more carefully at the structure of the software.</td>
<td>30 mins</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Questionnaire</td>
<td>Questions about the ease of use and utility of the HORIS software (see Appendix C)</td>
<td>10 mins</td>
</tr>
<tr>
<td>Prioritisation</td>
<td>Collation, confirmation and prioritisation of key issues identified by users during task and free play. Full group session.</td>
<td>30 mins</td>
</tr>
<tr>
<td>Questionnaire</td>
<td>Questions about the perceived quality of the workshops (see Appendix C).</td>
<td>5 mins</td>
</tr>
</tbody>
</table>
3.0 RESULTS

Only 6 of the 7 workshop sessions went ahead as planned because of a poor response for the Wednesday afternoon session on the 25th June. A total of 27 people participated overall. The groups were roughly divided into growers, consultants and 'technicians/seed company representatives'. Table 2 shows the actual role/titles of the participants.

Table 2 Role/title of workshop participants (only 13 responses)

<table>
<thead>
<tr>
<th>No.</th>
<th>Role/title</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Sales - seed merchants</td>
</tr>
<tr>
<td>4</td>
<td>Technical manager</td>
</tr>
<tr>
<td>2</td>
<td>Technologist</td>
</tr>
<tr>
<td>2</td>
<td>Product development manager</td>
</tr>
<tr>
<td>2</td>
<td>General farm manager</td>
</tr>
<tr>
<td>2</td>
<td>Director</td>
</tr>
<tr>
<td>1</td>
<td>Technical representative</td>
</tr>
<tr>
<td>1</td>
<td>Vegetable section manager</td>
</tr>
<tr>
<td>1</td>
<td>Crop analyser</td>
</tr>
<tr>
<td>1</td>
<td>Customer services/sales</td>
</tr>
<tr>
<td>1</td>
<td>Production director - ELGRO</td>
</tr>
<tr>
<td>1</td>
<td>Brassica manager</td>
</tr>
<tr>
<td>1</td>
<td>Vegetable trials assistant</td>
</tr>
<tr>
<td>1</td>
<td>Vegetable sales manager</td>
</tr>
<tr>
<td>1</td>
<td>Horticultural Consultant</td>
</tr>
<tr>
<td>1</td>
<td>Designer</td>
</tr>
<tr>
<td>1</td>
<td>No role/title given</td>
</tr>
</tbody>
</table>

The main purpose of the workshops and interviews was to identify problems with the software at any early stage in development so that the most important ones might be addressed prior to commercial release. Problems identified within the workshop and interview sessions are summarised below. 1 questionnaire was not returned, and not all respondents answered all questions, therefore the number of responses will not always equal 27.

3.1 Navigation related problems

Table 3: 'At any time were you confused as to what was happening'

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 4: 'Did you always know what to do next?'

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11</td>
<td>14</td>
</tr>
</tbody>
</table>
That there were problems relating to navigation, or moving around the system, within HORIS is illustrated by tables 3 and 4: 15 out of the 26 respondents said that they felt confused (see table 3) and 14 out of 26 said that they were not sure what do to next (see table 4) at some point during their use of the system. The comments associated with each of these questions suggest that the users felt that the problems they experienced were largely linked to inexperience, either with the system or with computers in general. However a number of more specific comments were obtained from the practical sessions which suggest ways in which the system could be improved for all users.

The problems identified within the workshop sessions relate to the tools used to navigate around the system (reference window, contents, search), to linking, and to the headings employed. Each point is summarised below with specific recommendations from users, full comments can be found in Appendix D. Items given an asterisk (*) were considered vital by the users involved in the workshops.

- **Reference window - function not obvious**
  Specific recommendations from users
  - Make 'reference window' more obviously different to distinguish it from the rest of the screen - at the moment it looks like a split pane.

- **Use of 'contents'**
  Specific recommendations from users
  - Index should have 'Index' or 'Contents' at top of the screen and should always open at the top.
  - It's hard to follow headings when lots of them are open; perhaps use a larger tab setting.

- **Use of Search tool**
  Specific recommendations from users
  - Provide 'Help' on narrowing from lots of hits to more manageable number (3/4 optimum)
  - Grade hits in order of importance i.e. what part of info it appears in
  - Index the labels of tables of statistics so that you can search for a specific table, also if possible, enable searching in table contents

- **Links - not enough of them**
  Specific recommendations from users
  - Lots more 'see also's
  - More back linking
  - Needs links between confusabale diseases/disorders/pests etc. & photographs - in fact links wherever possible.
  - Need to be able to link to all associated information from either product or active.
  - * Need active and product names close together so can always find whichever searching on.
  - HDC report summaries would be useful cross linked with pests and diseases.
  - Links between green book information and label information.
• Headings: too general/misleading
  **Specific recommendations from users**
  - The order of the headings needs to reflect the order in which users will approach the information i.e. problem then solution. The first headings should therefore deal with the identification of pests, diseases etc. and the later ones with their treatment.
  - Headings should not have 'Cabbage diseases' etc. in front of them when they relate to AI's. They should read 'Active Ingredient - diseases'.
  - The compatibility section for chemicals also contain non-compatibility information. Non compatibility should be in a totally different section where it needs to be mentioned, otherwise it could lead to expensive errors. (the information on the non-compatibility of Ramrod Flowable was given as an example).

• Headings: Information in wrong place
  **Specific recommendations from users**
  - Make Statistics a top level heading
  - Make separate headings for ID and life cycles
  - Descriptions of some items were under 'prevention and cure' - needs a specific 'description' heading.
  - Calendar of diseases should be in disease section not in propagation.

• Headings: New ones needed for additional information
  **Specific recommendations from users**
  - Want an 'organisations' heading containing names and contact details of relevant organisations
  - Want a harvest interval heading for harvest interval data.
  - Want a list of chemicals not divided into chapters - characteristics, compatibility's and how to use - for quick search.
  - Protocols - to contain NFU and Natures Choice etc.
  - Chemical information tables have not got labels.

• General problems
  **Specific recommendations from users**
  - Forms need clearly separating from the text.
  - Need to get to top of document quickly - perhaps a 'home' button.
  - Layer information - i.e. basics of chemical info at top then 'see also' compatibility, toxicity, environmental - link to general section at right point.

3.2 Content Related Problems

<table>
<thead>
<tr>
<th>Table 5: 'Generally how would you rate the information within HORIS?'</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Too detailed</strong></td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>
The level of detail used in HORIS was considered by the majority of users (18/26) within the workshops to be 'about right' (see table 5), although some felt that more detail was required for the 'expert' user.

General comments relating to the information concerned the need to provide reassurance that the information was accurate and recent. Details of source, checking and date last updated would be essential.

Table 6: 'Is the information contained within HORIS what you expected?'

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 6 shows that while the information contained within the system was as most respondents expected some felt that there were gaps. The workshops also highlighted areas where users would like to see more information. These are listed below with specific recommendations. Asterisk's indicate items the users consider to be vital to the success of the software.

- **More information required on: contacts/organisations**

  *Specific recommendations from users*
  - Manufacturer/supplier support - list of addresses to contact for more information.
  - What HDC is and does.
  - List of clinics or where to go for more information.
  - Clues as to what to do to distinguish between confusable items - even if its 'call HRI'.

- **More information required on: chemicals/products**

  *Specific recommendations from users*
  - *Much more information required on products/AI's to make it a useful management tool. Summary tables providing a one-stop overview of product characteristics was suggested by all groups for weeds and diseases. Characteristics which are useful and which would 'enable informed choice' are: range of items treated, harvest interval, COSHH information, favourite weather, indication of environmental acceptability, effect on beneficials; indication of protocol status.*

Other information linked to chemicals and which users indicated they required is:
- ICMS - BAA or LEAF material
- FWAG (Farming Group) information would be useful.
- Information on restrictions
- Protocols: Natures Choice; NFU protocols.
- Hazards
- Toxicology
  - *Assurance that listed chemicals are approved
  - **SOLA's - need to check legality of document in scanned/typed format.
- Protective clothing requirements.
- Alkaline sprays. It says within HORIS 'do not mix with alkaline sprays', yet when you do a search on alkaline sprays, there is not information on them.
- Registration codes, the system doesn't tell you what it is.
- Information on reduced applications.
- Actipron should be mentioned more than 4 times.
- Esfenvalerate is no longer usable, yet it is given as usable in HORIS.

**More information required on: varieties**

Specific recommendations from users

- * Trials information
- * Varieties - possibly experience suggested varieties for land types: table of characteristics; resistance ratings.
- Independent varieties information needs to be in the system (such as NIAB?)
• More information required on: projects
  Specific recommendations from users
  - * More detail on projects - keywords with projects as minimum, preferably
    precis, abstracts, executive summary, time-scales (has it finished yet?)

• More information required on: misc.
  Specific recommendations from users
  - There should be a very clear disclaimer within HORIS that all users will see
    each time they use it.
  - Section on HORIS. What it is, how to use it effectively.
  - All life-cycles, including predators.
  - Maybe some actives missing - Chlorothalonil (white blister).
  - Information on Oedema and its theoretical relationship with thrips on white
    cabbage.
  - Information on out of season production.
  - Information on spacing for a specified size.
  - Information on polythene or fleece for crop production purposes, not just for
    pest and disease protection.
  - Photos of different grasses and all weeds for identification purposes.
  - Rhizoctonia - didn’t mention field information, only information on seedlings.
    Need to cover all stages of plant growth.

3.3 Other points
A number of other points were raised which do not fit into the headings of contents
or navigation and these are listed below, again with user recommendations for
improvements.

• Updates
  Specific recommendations from users
  - *Updating critical to success of the software.
  - Updates should have ‘what’s new’ heading.
  - Monthly newsletters would be OK.
  - Information on when and how the system will be updated (SOLA’s should be
    monthly, other information as appropriate).

• Accuracy
  Specific recommendations from users
  - *Accuracy critical to success of the software.
  - Need to be reassured that product/active info and procedural information is
    accurate e.g. check for aphids from June should really be check from May - it
    has to be right - check that NFU etc. are giving the same message.
  - Green book information at present is not always reliable, needs to be checked
    before it goes into HORIS.
  - Change the ‘c’ for control in the weed control table to ‘s’ for susceptible, as
    this is the accepted industry standard. Also the black squares in the same
    table should read ‘mr’ (moderate resistance).

• Tutorial
  Specific recommendations from users
- Needs a tutorial. Use questions etc. to take through a realistic search.

**Notes**

*Specific recommendations from users*
- Collect any notes deleted by updates in a special folder.

**General**

*Specific recommendations from users*
- Concentrate on management side - support decisions - bring key information to the top.
- Important that HRI & NFU information converges rather than diverges
- Provide HRI comments/mailbox.
- Resolve screen resolution problems - text size and appearance of lifecycle picture.
- SOLA's - need to be able to print them off.
- Tables cannot be viewed in full, some of the information is off the screen.
- There needs to be 2 versions of HORIS, one that will work on low power machines with no pictures, another that has all the pictures.

### 3.4 Perceived utility of HORIS

Table 7: 'How do you feel overall about the HORIS system, based on your experiences in this workshop?'

<table>
<thead>
<tr>
<th>Very Neg.</th>
<th>Negative</th>
<th>Positive</th>
<th>Very Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1*</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

**Comment**

- Very encouraging to see a comprehensive information package on brassica crops.
- Because of content - accessibility of info from source
- Needs to be more detailed on chemicals, needs to be easier to user - i.e. not getting lost
- I think it will be a good general tool for all those involved in the production of veg. crops.
- *Need to obtain information from colleagues on their requirements*
- I think it could be very useful
- All data relevant to decision making is in one place and easily usable
- User friendly, good educational tool
- Useful tool, especially as a reference for inexperienced staff
- To have all useful information in one 'book'
- Very interesting and informative way of passing on current knowledge to 'the industry'
- Information would be useful for technical rather than commercial department

Responses to the question 'How do you feel about the HORIS system based on your experiences in this workshop' elicited a positive response from 13 out of the 14 respondents (see table 7), with 6 rating it highly positive. The one negative response was from a respondent who had been sent in place of a colleague and who was not sure what her colleagues requirements would be. Other comments associated with
this question related to its user friendliness and perceived usefulness as an information source.

Table 8: 'Do you think you would buy and use the HORIS system when it is completed?'

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Maybe</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
<td>14</td>
</tr>
</tbody>
</table>

While 10 people said they were definitely interested in buying the software (see table 8), 14 were not prepared to commit themselves. Six of these felt they couldn’t say without an idea of cost, two felt that more information would have to be in the system, two felt that in its current form it might not be of use within their companies and two felt it hard to comment on an incomplete system, and they would wait until it was ‘tried and tested’.

3.4.1 Best/most useful aspects
The workshop respondents listed a number of things that they felt were the best and most useful aspects of the system for them. These can be summarised under 3 main headings:
- Speed of access to information i.e. the collection of a wide range of information in one 'easy to use' package, clearly presented in bullet points
- Access to good pest and disease information: especially with pictures.
- Access to chemical information
The full list of comments can be seen in Appendix D.

Other positive points elicited during the workshop and summarised during the prioritisation session were as follows:
- Photos very good
- Easy to use
- Would be great if could become central database for horticulture.
- Different methods of finding data
- Speed of access
- Good clear bullet points
- Good first impression
- Saves heaps of books
- Useful in different parts of the company

3.4.2 Worst/least useful aspects
Users were also asked which were the worst aspects of the system for them and these can be summarised under the following 3 headings:
- Finding information:
  Using 'query' and 'contents' and links within a mass of information were mentioned as problems. These are dealt with in more detail in section 3.1.
- Information missing:
  Variety information and some factual information (see section 3.2).
- Information needs to be complete and continuously updated.

3.5 Other crops
Workshop participants were asked which other crops they would like to see HRI produce information systems for. Table 9 shows their responses. The crops have been grouped according to crop type and in the order of priority indicated by the respondent, the column 'No rank' refers to cases where no priority was assigned by the user.
Table 9: 'What other crops would you like to see available, in order of their importance?'

<table>
<thead>
<tr>
<th>Crop</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>No rank</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brassicas All</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>Brassicas B. sprouts</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Calabrese</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Spring Greens</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Alliums</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Onions</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Leeks</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>S. Onions</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Salad crops</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lettuce</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cucumber</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Root veg</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Carrots</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Parsnips</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Potatoes</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Legumes</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Peas &amp; beans</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Spinach</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Herbs</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Parsley</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cut flowers</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Courgettes</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Strawberry</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Oriental Veg</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

It should be noted that only those interested in brassica crops were invited to attend the workshop and it is therefore not surprising that the majority wanted more information on brassicas. Other crops which seem to be of interest to this group of people were the alliums, salad crops, root vegetables, potatoes and legumes.

3.6 Other comments

Users were given space to make any other comments about the system and their replies are given below:

- I would like to try it when it is finished.
- Very useful package - it would be aided when pictures are available.
- When bought to market could there be a package deal for the likes of a seed company needing to supply, say up to 8 reps with this program.
- Clear presentation made the system very user friendly. It would be helpful if the trial information issue could be resolved.
- Internet services with real time up to date info on current season pests, disease etc.
- In all a useful tool, wish every success with the project.
- Addition of product to actives in some chemical details. Dates of SOLA etc. overall good and very promising.
- Impressed with the potential for updating in the field.

It would seem that the tool was received very favourably by those who commented.
3.6 Quality of the workshop sessions

Table 10: Ratings for quality of the workshop

<table>
<thead>
<tr>
<th>Very poor</th>
<th>Poor</th>
<th>Good</th>
<th>Very Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>-</td>
<td>8</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 11: Ability to comment fully on the HORIS software.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>5</td>
</tr>
</tbody>
</table>

Participants were asked how they rated the organisation of the workshop on a four point scale from 'Very poor' to 'Very good'. The response was very positive: of the 21 participants responding, 8 rated the organisation 'Good' and 13 'Very good' (see table 10). Not all felt they had been able to comment fully on the software however, as table 11 shows. Five participants felt they were unable to comment fully, their comments (see Appendix B) suggest that this was due to a shortage of time and the incompleteness of the package but that they understood the reasons for both.

Other comments were largely positive although the last two reflect a concern with the level of training in the first workshop session:

- It would be nice to see a completed version to see whether pictures etc. enhance the effectiveness of the package.
- Better for being a small number of people
- Thoroughly enjoyed session. Very useful concept. Requires market orientation to ensure commercial success.
- Excellent level of interest, enthusiasm, and ability.
- Possible training on system before use.
- Improve 'tutorial' on software, prior to use.
CONCLUSIONS AND RECOMMENDATIONS

The main impression from the workshops was that the HORIS software was considered to be a timely and useful package for a range of users within the brassica sector. User comments suggest that bringing all the relevant information together in electronic and searchable form will be invaluable. Aspects which seem to provide the most 'added value' were the inclusion of SOLA's in a form which would be considered legal and access to up-to-date and accurate information on chemicals and their use.

The trials were however intended to highlight those aspects of the system which are not currently optimum, and therefore allow improvements prior to commercial release. The main problems identified by the users were largely contained under the headings of navigation and content. Comments relating to the 'Reference window', 'Contents' and the 'Search' tool are directed at the Folio Views Shell and may therefore be harder to address. The recommendations for Folio Views would be:

- Use negative video, font or background colour to distinguish the Reference Window from the main text window.
- Place a 'Contents' title on the top of the contents page.
- Always open the 'Contents' at the top of the page.
- Expansion of the search tool facility could include the ability to grade the hits (as in Web based search tools) and access to tips on successful search techniques.

The rest of the navigation problems are completely within the scope of the project to address and relate to links and headings. Recommendations are made relating to these and other topics for changes to the prototype. Comments or points made by the users but not included in the recommendations should not be ignored, they are equally valuable but not as time critical or immediately relevant as those indicated below.

There were simply not enough links between related subjects. Users, particularly those accustomed to Web and other hyper-link based documents, expect to be able to move between sections by clicking on related words. Very few of these possible links had been implemented by the date of the workshop. Many more 'see also's' and 'backlinks' are also required. The recommendation is therefore:

- Create links wherever it is possible to do so for the first instance of the link phrase in a section or every 3 inches of full text for long sections.
- If a direct link is not possible but there is related information use 'See also' to indicate this to the user.

Tables are also a problem, they contain information which people want to search on and to link to but, as they only exist as objects, neither operation is possible. If it is not possible to produce proper tables in Folio Views then it is recommended that:

- A list of key words be provided at the bottom of each table to facilitate search.
- There is the ability to search on the headings of tables, and these should be very informative as to the table contents.

Headings used in the prototype system caused problems for users for several reasons, either they were seen to be misleading, they were in the 'wrong place' or
they were not there at all. While this topic generated a lot of comments it should be a relatively simple matter to resolve. The recommendations are:
- Rethink the structure of the headings from a problem oriented point of view.
- Check and re-label/create headings as per user suggestions.

There appears to be a general problem relating to the structure of the shell and the, mostly 'psychological' limitations that it imposes. The Folio Views software is somewhere between a book and an electronic hyper-linked document. A book has a start and end and chapters which flow one from the other, it is one long continuous string. A hyper-linked document can be totally modular, each section of information can exist alone and be linked to any other section in any order the user/designer desires. This means that information can be more easily 'layered', permitting rapid viewing of top level information and access to more detailed information only when required. This is particularly useful for software serving many levels of technical and scientific competence. It is possible to make HORIS much more like the type of hyper-linked document available on the Web, and given the opportunities afforded by that medium, it would be sensible to design something that can be used in both without too much additional work. The recommendation from HUSAT for HORIS is that:
- the structure and linking of the 'book' are reconsidered to make them closer to those proposed for the Web pages.

While most of those involved in the workshops felt that the information HORIS contained was pitched at about the right level, there were many suggestions for increasing the scope of the content. The two areas which elicited the most interest were those relating to chemicals and varieties, recommendations are:
- Provide a summary table of chemicals and their ratings on the following attributes: range of items treated, harvest interval, COSHH information, favourite weather, indication of environmental acceptability, effect on beneficials; indication of protocol status.
- Include a statement which states positively that chemicals are approved.
- Ensure that the SOLA's are in a form which makes them legally acceptable and make that clear within the 'book' and in publicity.

- Provide trials information
- Provide a summary table showing variety ratings on: suitability for land types; all characteristics for resistance etc.

The utility of the chemical and variety information depends to a great extent on the faith that users have in its accuracy, completeness and relevance. Recommendations to reassure users are:
- Provide indicators of the source of material
- Date each chemical and variety related entry

Other contents related recommendations are:
- Provide keywords and dates with project descriptions as a minimum. Where possible include an abstract or precis.
- Provide a section on HORIS
Other recommendations from the workshops are:

- Define and publicise the updating process, this will be a critical determinant of the software's success.
- Double check the accuracy of the information contained within the brassica manual, perhaps give beta copies to a selection of advisers in exchange for critique.

A summary of these recommendations is provided in Appendix E.

In conclusion, it would appear that the software has to a large extent met the requirements identified by the users in the earlier part of the project. Changes to the structure and content of the brassica manual identified within the workshops will increase the software's attractiveness to its target audience as well as improve its general usability. Definition of methods to ensure the accuracy and validity of the informational content will help to ensure its value to a wide section of the brassica industry.

The workshops themselves were seen to be a valuable means of collecting users views on the software although more preparation time would be recommended in future.
APPENDIX L:
TIM Final Report


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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## Section 1: Identification sheet

<table>
<thead>
<tr>
<th>(a) MAFF Project Code</th>
<th>HH9913T</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b) Project Title</td>
<td>A framework to improve the uptake of computer models within the UK horticulture industry</td>
</tr>
<tr>
<td>(c) MAFF Project Officer</td>
<td>Dr Seal</td>
</tr>
<tr>
<td>(d) Name and address of contractor</td>
<td>Horticulture Research International Wellesbourne, Warwick</td>
</tr>
<tr>
<td></td>
<td>Postcode CV35 9FF</td>
</tr>
<tr>
<td>(e) Contractor's Project Officer</td>
<td>Dr G.M. Tatchell</td>
</tr>
<tr>
<td>(f) Project start date</td>
<td>01/09/1996</td>
</tr>
<tr>
<td></td>
<td>Project end date</td>
</tr>
<tr>
<td>(g) Final year costs:</td>
<td>approved expenditure</td>
</tr>
<tr>
<td></td>
<td>actual expenditure</td>
</tr>
<tr>
<td>(h) Total project costs/total staff input:</td>
<td>approved project</td>
</tr>
<tr>
<td></td>
<td>actual project expenditure</td>
</tr>
<tr>
<td></td>
<td>*approved staff input</td>
</tr>
<tr>
<td></td>
<td>*actual staff input</td>
</tr>
<tr>
<td>Date report sent to MAFF</td>
<td>05/11/1997</td>
</tr>
<tr>
<td>Is there any Intellectual Property arising from this project?</td>
<td>NO</td>
</tr>
<tr>
<td>Staff years of direct science effort</td>
<td></td>
</tr>
</tbody>
</table>

Date project completed: 31 August 1997
Section 2: Scientific objectives / Milestones

2. Please list the scientific objectives as set out in CSG 7 (ROAME B). If necessary these can be expressed in an abbreviated form. Indicate where amendments have been agreed with the MAFF Project Officer, giving the date of amendment.

1) Do a formal financial appraisal to assess the different costs and benefits of a range of scenarios for data collection and information provision, that are required for the implementation of model based decision support systems.
2) Develop training tools for showing growers and advisors the potential of model-based decision support systems.
3) Improve the awareness of the benefits of model based decision support systems to growers and advisors within UK horticulture through structured workshops
4) Identify the output requirements of growers and their consultants for model based information.
5) Determine the economic viability of an on-going service to provide the model-based information to growers and advisors

3. List the primary milestones for the final year.

It is the responsibility of the contractor to check fully that ALL primary milestones have been met and to provide a detailed explanation if this has not proved possible.

<table>
<thead>
<tr>
<th>Milestones</th>
<th>Target Date</th>
<th>Milestones met?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number Title in full</td>
<td>on time</td>
<td>in full</td>
</tr>
<tr>
<td>03/03 Analyse data and provide information to financial appraisal</td>
<td>01/05/1997</td>
<td>YES</td>
</tr>
<tr>
<td>04/03 Report user preferences and needs to model developers (publication in preparation)</td>
<td>01/05/1997</td>
<td>NO</td>
</tr>
<tr>
<td>04/04 Reports findings to growers and levy bodies (publication in preparation)</td>
<td>01/05/1997</td>
<td>NO</td>
</tr>
<tr>
<td>05/03 Report findings to growers and levy bodies (publication in preparation)</td>
<td>01/05/1997</td>
<td>NO</td>
</tr>
<tr>
<td>Final project report to MAFF</td>
<td>30/09/1997</td>
<td>YES</td>
</tr>
</tbody>
</table>

If any milestones have not been met in the final year, an explanation should be included in Section 5.

Section 3: Declaration

4. I declare that the information I have given in this report is correct to the best of my knowledge and belief. I understand that the information contained in this form may be held on a computer system.

Signature: [Signature]
Name: C.A. Price
Position in Organisation: Chief Executive
Model-based decision support systems (DSS) are becoming essential tools as consumers and retailers increase the pressure to reduce agrochemical inputs to horticultural crops. Although a substantial portfolio of models now exist, their uptake by the horticultural industry has been disappointingly slow. This project has been concerned with three issues which, it is believed, have had a strong impact on uptake:

- Poor understanding of the nature of model-based DSS, their strengths and limitations
- Poor targeting of existing models
- Understanding of the economic feasibility of providing the local weather data required by most simulation models.

The project developed and tested a modular 'workshop' framework to identify areas where growers and consultants need more scientific support and to provide growers and consultants with a better understanding of the utility of DSS in their specific sectors. Financial appraisals based on different availability of meteorological data have also been conducted to assess the costs and benefits of using predictive models on grower holdings in the top fruit and brassica sectors.

The project identified that:

a) A full UK wide awareness programme for growers is required over the next 12 months if effective application of models is to be achieved.

b) A clear understanding of growers and consultants' requirements for model-based DSS are essential if they are to meet the industries needs.

c) The workshop format developed within the project is sufficient to meet the needs of a) and b) and should be tailored to suit a variety of formats for giving and gaining information e.g. shows, roadshows, local group meetings, etc.

d) The areas in which existing models could be of great use to the brassica and top fruit sectors but there are many others where models are still required. The workshops also identified specific questions which the design of the DSS would have to accommodate.

e) A number of other key issues relating to the DSS development process:
   - users want early release of 'unfinished models' with appropriate documentation of their weaknesses
   - 'suites' of pest and disease models are required if the systems are to be used seriously. Tackling a single problem is not sufficient.
   - integration of farm data with DSS's is required to prevent double entry of information
   - linking of DSS output to other systems is required to prevent double entry of information e.g. Growact forms
   - more 'encyclopedic' information with DSS (e.g. HORIS) would make the systems more useful.

f) That under all the scenarios tested for both brassicas and apples there was a very positive net financial benefit from having easy access to predictive models and on-farm weather data.

g) There was little difference between the economics of providing on-farm weather stations and providing a networked service.

h) The area of crop represented by a single weather station is a critical factor in the economics of using models. Further research in this area is essential.

i) The process of calculating the savings that the use of model-based DSS may provide brought about an attitude change in some participants. This process could be developed to encourage the use of DSS.
1.0 INTRODUCTION

2.0 EDUCATIONAL WORKSHOPS

2.1 METHOD

2.2 SESSION A RESULTS

2.3 SESSION C RESULTS

2.4 WORKSHOP QUESTIONNAIRE RESULTS

3.0 FINANCIAL APPRAISAL

3.1 METHOD

3.2 RESULTS

4.0 CONCLUSIONS AND RECOMMENDATIONS
UK horticulture is a highly sophisticated industry that relies heavily on technological developments to remain competitive. Considerable MAFF and industry investment has been directed at the elucidation of processes of plant development and of their pests and diseases in horticultural crops. However, the uptake of these models by the horticulture industry has been disappointingly slow.

Many growers have obtained computers in the last few years and use them primarily as data storage tools for financial and legal purposes. The potential of model-based decision support tools remains unrecognised by many, not because they are not needed, but because their utility has yet to be recognised.

New technological developments providing modern software and improvements to the capture of weather data provide new opportunities to increase the rate of uptake of models by growers. However, in addition to the technological developments effective two-way communication between grower and researcher must be established to ensure that:

- growers are aware of the models available along with their potential application, scope and limitations
- the research community targets its work at the issues of most importance to the industry, designing models in a form that is useful and usable within the industry

The objectives of this project were to:

i) Develop training tools for showing growers and advisers the potential benefits of model-based decision support systems.

ii) To improve awareness of the benefits of model-based decision support systems to growers and advisers within UK horticulture through structured workshops.

iii) Identify the requirements of growers and their consultants for model-based information.

iv) To determine the perceived value of models and weather data to growers.

v) To undertake a formal financial appraisal to assess the costs and benefits of a range of scenarios for data collection and information provision that are required for the implementation of model-based decision support systems.

vi) Determine the economic viability of an on-going service to provide the model based information to growers and advisors.

During February and March 1997, a set of 6 workshops were carried out. Three workshops took place at HRI East Malling with members of the Apple growing industry. Two workshops took place at HRI Kirton and one at HRI Wellesbourne, both with members of the Brassica growing industry. This report details the method used for the workshops, the results obtained, discussion of the results and recommendations for the future.
2.0 EDUCATIONAL WORKSHOPS

2.1 Method

2.1.1 Design

The purpose of the workshops was threefold:

• To determine what growers and consultants want from models.
• To inform growers and advisers of the concept and potential of computer based models.
• To assess the perceived monetary value of predictive models to the horticultural enterprise.

A number of requirements were identified for the workshops to ensure their success, these being:

• Each workshop should be small enough to allow each participant to make a contribution and to allow group discussions.
• The workshop itself should be evaluated by the participants.
• The workshops should take place to coincide with the 'quiet period' for growers and advisers - i.e. November to March.
• The workshops were to be kept to a maximum of three hours, to encourage growers and advisors to attend.

2.1.2 Users

Six workshops were carried out during February-March 1997. All sessions were in the morning (9.30am for all workshops except Wellesbourne, which started at 10.30am) and took place, on the following dates, and with the following attendees:

• 26th February at HRI East Malling for 4 growers in the Apple sector.
• 11th March at HRI Kirton for 7 consultants in the Brassica sector.
• 12th March at HRI East Malling for 4 consultants in the Apple sector.
• 13th March at HRI Wellesbourne for 6 managers in the Brassica sector.
• 18th March at HRI East Malling for 3 managers in the Apple sector.
• 19th March at HRI Kirton for 3 consultants and 5 managers in the Brassica sector.

It should be stated at this stage that the optimum number of attendees for an interactive workshop of this kind is between 5 and 9.

2.1.3 Workshop Structure

The timetable for each workshop was as shown in Table 2.1 below.
To ensure that the expectations attendees had were reflected in the content of the workshop and
As part of the evaluation of the workshops, as attendees perceptions of models pre and post-workshop could then be assessed

Questions covered were:

- Role/title
- Reasons for attending the workshop
- Previous experience with models and how useful they found them
- What their expectations were from the session
- Any other comments

The pre-workshop questionnaire is shown in Appendix C.

**2.1.3.3 Session A: Growers' requirements**

Workshop participants were asked to split into groups (the number of groups depended on the number of participants at that workshop, and ranged from 2 to 5 people in each group) to focus on what were the most important problems they faced in their work and the questions they needed answers to. Each participant also had an explanation sheet of the session in their folder (shown in Appendix D). Participants were encouraged to think of all areas, not just those where they thought models could help. A facilitator was placed in each group to encourage discussion, ask supplementary questions on fruitful routes, and provide prompts where necessary in broad areas such as pests, diseases, nutrition, irrigation, quality, harvest etc. The facilitator also taped the session, with the participants permission, for later analysis.

Then the groups came back together and the areas identified as a result of the discussion were recorded on two flipcharts and participants invited to comment further where they thought necessary, and also to prioritise the questions.

The purpose of this activity was to identify those areas where participants felt they needed more information to be able to perform their jobs better, and to identify those areas where model-based decision support systems could help.

**2.1.3.4 Identification of where models can help with the needs of growers as identified in the workgroups**

After refreshments, the workshop facilitators went through the areas identified in the workgroups and identified where there were models already available to help in an area; where there were models in progress; and where models could be created in the future. Also identified were those areas where models were not applicable and an explanation was given as to why.

In this way workshop participants could see how present and future model-based decision support systems could help them in those areas they had identified as important to them in their work, and where models could not help, and why.

**2.1.3.5 Session B: Talk on models.**

The guest speaker for the workshop was introduced. For Brassica workshops the guest speaker was Dr Roy Kennedy and for the Apple workshops, Dr Mike Solomon. Speakers were experienced modellers in the area of interest to the workshop participants, and the
talk covered what models were, how they worked and a specific example of a model and the kind of help that models could give. The talks were based on a standard structure (see Appendix E). Guest speakers were asked to cover all the main topics using examples from their own experience.

After the talk there was a short question and answer and discussion session, and information from this session is reported with the information collected during the discussion of user needs.

2.1.3.6 Session C: Assessment of the perceived monetary value of predictive models

Workshop participants were introduced to Session C of the workshop. The slow uptake of models in the horticultural industry was explained, and the availability of appropriate weather data was highlighted as a factor and the different options for supplying weather data were described. The purpose of the session was explained: to determine the perceived value of models to the workshop participants.

The participants were split into two groups, each with a facilitator, and asked to work through the implications of either the imposition of the increasing pressures to reduce agrochemical input to the growing of horticultural crops. Two specific scenarios were considered:

- A 100% agrochemical tax imposed over two years
- A mandatory agrochemical reduction programme achieving a 50% reduction within two years.

Each scenario was worked through twice, firstly presuming limited access to predictive models and the weather data to run them, and then presuming easy access to predictive models and the weather data to run them. A sheet was given for each situation for the group to enter the financial implications of each scenario for a specific crop (the sheets used are shown in Appendix F). Discussion was taped for later analysis.

The groups then came back together and the results of the different scenarios were reported and discussed further. This discussion was also taped for later analysis.

2.1.3.7 Workshop Evaluation Questionnaire.

The workshop was then brought to a close, the attendees were thanked for their participation and asked to complete an anonymous workshop evaluation questionnaire.

This questionnaire asked the participants to evaluate the workshop in terms of the following:

- The organisation of the workshop
- Whether they felt they had enough information
- Whether they felt they had been able to comment fully
- Their view of the usefulness of models and model based decision support systems based on their experience of the workshop
- The main areas of decision making where they thought they could make use of models or model based decision support systems
- Whether they thought they would use model based decision support systems and what they thought the main barriers to use would be
- Any other comments

This workshop evaluation questionnaire is shown in Appendix I.
2.2 Session A Results

During the workshop, growers and advisers were asked to give their thoughts on what would be the most important and useful information for them in making decisions. These sessions were very successful and this document provides a summary of the groups responses.

Most of the information is relevant to both Brassica and Apple growers, therefore the comments are combined and presented here as one set of comments to prevent repetition. Where comments and suggestions are specific to the Apple or Brassica growers, this is indicated in the heading.

The information is presented as a list that would take you through the year, from selecting a variety or planting an orchard through to picking/harvesting, storage and marketing the crop, and the information that growers and advisers would like more of, or help in interpreting, at each of these stages (sections 2.2.1 to 2.2.27). Then there are issues that are more general and related specifically to perception and use of models in the industry (sections 2.2.28 to 2.2.31)

2.2.1 Updated Information on plant varieties: Brassicas

- A central and regularly updated database on variety information, with the option to search on specific characteristics or groups of characteristics.

2.2.2 Information needed when planting a new orchard: Apples

- A blueprint or checklist of the events to consider before planting a new orchard, with enough flexibility for people to manipulate it to fit with their own interests.

2.2.3 Spacing models: Brassicas

- Models for different crops showing what will happen in terms of yield and quality if the density of the crop is changed.

2.2.4 Identifying the level of risk associated with a decision

- An indication of future risks, so you can be proactive rather than reactive. An example would be where a situation did not require immediate attention, but if weather conditions changed, no matter what you spray you will not get rid of the problem, as the chemicals can be non effective in certain conditions and what was a simple issue could become a major problem.

- To have a feel for the risk level of a particular course of action.

2.2.5 Information to determine whether to spray or not:

- Help to identify the pest or disease.

- Help in defining when a threshold has been exceeded.
• Information on the pest and disease lifecycle and behaviour patterns, when they arrive, when they will increase or decrease based on other information such as temperature, predators, crop conditions, fungal diseases within pests, and when they leave or become dormant.

• Information on the predator lifecycle and behavioural patterns, when they appear in the orchard or field, the size of the population, the effects of weather etc.

• More information on the predator-pest relationship.

• Information on the stage of the lifecycle where certain chemicals are effective.

• Information on other treatments that are available, not just chemicals.

• Information on the knock-on effects of spraying (such as damaging predators and chances of resistance build-up).

• Information on the harvest interval needed for that crop, linked to the spraying decisions.

• To be aware when one treatment covers for more than one pest or disease.

• Information on what to do in situations where resistance already exists.

• The growth rate of the plant needs to be incorporated in a model when deciding on whether to spray, because if there is a rapid growth spurt, there may be a need to spray even if the chemical is still active, because new leaves will not be covered.

• Past history of fungicide use.

• Susceptibility of the variety.

• Costs.

2.2.6 Information on what chemical to use and the rate:

• Up to date and complete information on the efficacy and mode of action of products, including efficacy and longevity of the spray based on information such as weather and environmental aspects (ie. disease pressure).

• Kickback and protection curves for different chemicals.

• Up to date and complete information on what is presently available, what off labels are available and what has gone off the book.

• A system that takes into account the efficiency of the spraying technique used (how much of the spray actually reaches the target).

2.2.7 Information on the timing of a spray:

• Information on the spray window (what leeway there is on the timing of a spray).

• Information on the behavior of the pest or disease to ensure correct timing and maximum benefit from the chemical.
2.2.8 Justifying and auditing spraying:

- A system which allows the reasons for actions to be followed and audited.
- To be able to predict future events and justify preventative spraying to a level that the customer and multiples will accept.

2.2.9 Spray planning

- To be able to have a work planner that could give a complete spraying plan for each crop. Select can do some of this, but each treatment for a crop requires a different plan, so that renders it useless for work planning.

2.2.10 Difference in acceptable disease levels at pre and post marketable crop: Brassicas

- To be able to have a system that knows when the marketable crop comes in and can adopt a different strategy at that point (from tolerating a threshold to no tolerance).

2.2.11 Weeds and the application of herbicides: Apples

- Information on the emergence of weeds.
- Information on the best time to spray for different species of weeds.
- Information on how important it is to spray for different species of weeds, are they damaging to the crop or not?

2.2.12 Nutrition: General

- To have a system that could help you to answer the question 'what are the specific nutritional requirements for field x, crop y at growth point z'.

2.2.13 Nutrition: Brassicas

- To know what is really available to the crop and what is required at each growth stage so you can react.
- To know how the weather affects the uptake of nutrients.

2.2.14 Nutrition: Apples

- The present data available in this area may not be applicable for new varieties, and should be updated to reflect new varieties and especially the use of smaller trees with less reserves of nutrients.
- More information is needed on the times when certain nutrients are required, at present there are standard applications which are seen as a bit 'rough and ready'. However this was seen as an area that may not be cost effective because the research needed would be vast, and the cost of fertilisers is not that high. However if
In the future there were restrictions placed on fertiliser use, this would become a more important area.

- To have a system to record analyses of trees, with colour coding to indicate those that are high, medium or low in certain nutrients.

2.2.15 Irrigation: Brassicas

- More information on the effects of irrigation timing and amounts, and optimum timing and amounts for specific crops to maximise yield and quality.
- Information on the financial benefits of irrigation for different crops, a kind of 'league table' to enable targeting of limited water and equipment.

2.2.16 Irrigation: Apples

- Irrigation is not that widely used for top fruit, however given the possible future restrictions on water and changing weather conditions, it was highlighted as an area that may need more attention in the future.

2.2.17 Harvest/picking date: General

- To have all the factors that affect the harvest/picking date in a model, input the variables (such as temperature or sunshine hours), and know the specific date for a particular orchard or field in relation to the general picking / harvesting date.

2.2.18 Maturity predictions: Brassicas

- A prediction system for the probable maturity date, yield and class, taking into account varietal differences, location, weather and other relevant factors. This would allow better manipulation of the markets.

2.2.19 Picking/harvest date: Apples

- To know the likely storage life of fruit with more confidence, and to have an optimal picking date that takes storage life into account.

2.2.20 Storage: Apples

- A system that can help answer the question 'what is the right mix of nutrition that I need for this crop in this field to reach the required level of nutrition to enable storage?'.
- The main problem in this area would be if there were restrictions placed on chemical use.

2.2.21 Storage: Brassicas

- A model to tell us the ideal storage conditions to minimise weight loss and maintain quality.
2.2.22 Shelf life: Brassicas

- After picking, crops begin to lose weight, and it would be useful to know the weight loss over time given the prevailing conditions.

- Would be useful to know the factors that affect the shelf life of products, and be able to adjust the inputs to a crop to achieve a better shelf life.

2.2.23 Drenching for storage rots: Apples

- To be able to quantify the level of risk given the conditions to determine whether the fruit should be drenched.

2.2.24 Marketing Information: Apples

- To be able to more easily determine what is being harvested from each crop in terms of quality and financial return. Also to be able to determine what financially is down to an orchard's ability to produce, and what is down to the time the crop was sold.

2.2.25 Marketing Information: Brassicas

- To know what our customers have got programmed everywhere because if there is a lot of cauliflower coming in and the customer has set up a promotion of calabrese, then there is a problem that we could alleviate if we knew in advance about it.

2.2.26 Worst pests and diseases

The most important pests and diseases will depend on the farm location and weather. However from all the workshops, the following pests and diseases were identified.

<table>
<thead>
<tr>
<th>Brassicas</th>
<th>Apples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aphids</td>
<td>Scab</td>
</tr>
<tr>
<td>Caterpillars</td>
<td>Mildew</td>
</tr>
<tr>
<td>Ringspot</td>
<td>Tortrix</td>
</tr>
<tr>
<td></td>
<td>Caterpillar</td>
</tr>
<tr>
<td>White Blister</td>
<td>Blossom Wilt</td>
</tr>
<tr>
<td>Cabbage Root</td>
<td>Detritus</td>
</tr>
<tr>
<td>Fly</td>
<td>Canker</td>
</tr>
<tr>
<td>Red Fly</td>
<td>Coding moth</td>
</tr>
<tr>
<td>Spear roy</td>
<td>Rosy apple aphid</td>
</tr>
<tr>
<td></td>
<td>Red spider mite</td>
</tr>
</tbody>
</table>

2.2.27 Industry perception of models.

- Do not sell models on cost savings, but instead sell them on improved quality, targeting and benefits to the environment, getting the job done better, and earning growers bonus points with the customer.

- Models need to be correct for growers to have faith in them.
• People should be more educated on what to expect from a model as some people seem to hold the view that because it is technology it should be decision making and become uncomfortable if they have to input subjective data, and the output from the model is then based on that data. It needs to be clear that model based decision support systems are a guide rather than exact.

• Any system needs to provide better data with which to work, decision support, not decision making, the computer should provide you with all the information that you want and then you make the decision.

• Model data needs to be local.

• Any system should prompt people to consider issues or chase up their advisor when appropriate.

• Advisors will probably want a lot more background information in models than growers will.

2.2.28 User Input to models

• Data gathered by growers and advisors is often inaccurate, and if that is used to run the models, the model output will be inaccurate.

• Any model needs to be tested in a very robust manner on the assumption that it is an idiot that has entered the observed information, or use tools that take the guesswork out of it.

• The problem with so much gathering of information is how you gather it in a way that is not too expensive, can be easily processed and is idiot proof.

• There is a lot of technology but its uptake is going to be slow due to cost, the technical competence of the users and the fact that the person who might have to download the information may be the tractor driver. The whole chain has to be catered for. If you need a laptop, the spray driver, who may be a brilliant tractor driver and sprayer, may have oversized fingers or something and may hit several keys at the same time and not be sure he hit the right one in the first place. This is a problem.

• Any system has to be quicker than what is done now.

2.2.29 Benefits of early release of models to the industry

• Models should be available to the growers early, because even partially accurate data would be better in some situations than what is presently available, and the use could speed up the development. However early models should be released with caveats as to their use and also with adequate back-up.

2.2.30 Need for new models and integration of different models and their data

• Models that can be expanded to include prediction forecasts of more pests, ideally every pest you could have.

• Need integrated systems to answer the main questions leading to identifying how to get the crop to the supermarkets in terms of size, quality and pest and disease free.
• You want models that you can get separately, but they all should be able to work together so they all come into the same station, you should be able to enter your weather data and have that relate to all the models you have.

• More growth based information needs to be included in models. More basic encyclopedic information. Storage rots for instance.

• Pictures to enable identification. The way technology is going a simple picture could be entered as a quick reference.

• To be able to link all the information together, so you do not have to enter information for one disease, then the next disease etc. Need a model for a whole range of diseases.

• To be able to enter one set of information to give you all the information on a crop.

• Help in identifying the optimum level for all inputs, not just chemicals.

2.2.31 Linking model output to Growact forms

• When you are filling in the Growact form, information that is already in the system should transfer across automatically, including harvest intervals.

• Growact forms to be a permanent and unalterable record.
The objective of session C was to assess the perceived monetary value of predictive models to the horticultural enterprise. The discussion sheets used in this session (Appendix F) proved to be invaluable in structuring the discussion and thought processes through a series of logical steps.

By its very nature the discussion had to be based on grower speculation about the possible effects of future scenarios. The output from the session has successfully yielded three products:

a) An idea of the potential value of models on the gross margin of a crop (given the term the 'gross margin value')

b) A view of the current price that growers might be willing to pay for models (given the term the 'expected price')

c) An in-depth view of the aims and objectives of growers and how growers see models assisting them in meeting those objectives.

We believe that these structured discussions achieved a valuable teaching role. Through their own thought process, growers identified that the potential gross margin value was significantly higher than their 'expected price' valuation.

As expected the discussions yielded a wide range of options on how the scenarios might be tackled. It is a complex issue and how the market would react in a real situation would depend on a wide variety of factors. It is not appropriate to consider that the individual values obtained have any absolute accuracy. However, the trends and order of magnitude of these values provide an interesting insight into how the industry is thinking at the current time. It would be interesting to complete a follow up study in three years to see how attitudes have developed.

The sessions were most successfully concluded when the attendees, rather than the facilitator, presented the results from their session back to the whole group. This led to further discussion of the issues, an ownership of the conclusions reached, and most importantly the participants enjoyed it more.

### 2.3.1 Valuations

The financial conclusions reached by each discussion group are given in Appendix G (Tables G1 to G10). Each table provides:

a) The baseline financial profile taken from Nix (1996) for the crop concerned.

b) The predicted profile if there was limited access to predictive models and weather data.

c) The predicted profile if there was easy access to predictive models and weather data.

d) A calculation of the 'Gross Margin Value' of predictive models. This is calculated as the difference between the gross margin in c) (access to models) and the gross margin in b) (limited access to models). This difference (the additional gross margin benefit) is added to the 'Expected Price' which was incorporated as a cost when calculating the Gross Margin of c).
e) The current price that growers might expect to pay (the 'Expected Price'). This was included when the participants were deriving the detailed financial profile (see Appendix F) but before they had calculated the Gross Margin value.

One group on 13.3.97 were not prepared to commit to final figures on the financial profile.

Tables 2.2 and 2.3 provide a summary of Appendix G tables G.1 to G.10 grouping the results into the two scenarios presented.

2.3.2 Discussions

The discussions which led to the figures presented were tape recorded.

The specific tactics of each group varied in their attempt to address the scenario presented. Some groups considered higher intensity growing techniques, some increased use of fleece, whilst others concentrated on the increased use of resistant varieties. The discussions clearly highlighted that there are a wide variety of techniques available to growers should these scenarios become reality. There would be a clear need for research on which combination of approaches are likely to yield the best economic results in the long term.

Despite this variation in tactics there were a series of key issues which influenced the thinking of all groups:

- Maintenance of the quality of the produce was paramount. The risks of loosing market share and income through poor quality were so high that all participants were very cautious about reducing chemical inputs. In the case of the 100% Agrochemical Tax nearly all participants were prepared to pay the higher prices in order to ensure the quality of their produce. A scenario such as this is therefore unlikely to reduce the application of agrochemicals on UK horticultural produce.

- Reduced agrochemical input is likely to be replaced by increased labour input. This would include increased monitoring of the crop, increased manual grading and packaging of the produce and increased hand weeding.

- Models are not considered by growers as a tool for reducing costs. The potential savings are very small in comparison to the potential risk of loosing the full marketable yield of a crop if something goes wrong. In a scenario where agrochemicals must be reduced, either through government legislation or consumer pressure, then the value of models will be to provide the grower with an additional insurance to ensure agrochemicals are applied when they are needed. Faith in the accuracy of models is limited at present. They do not replace, but compliment, existing knowledge and procedures. A quote from one participant indicates the issue clearly:

"It is not what you save, it is how much you have to spend to stay in the game"
Table 2.2 Summary of results

<table>
<thead>
<tr>
<th>Scenario: Mandatory Reduction Programme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>Calabrese</td>
</tr>
<tr>
<td>Calabrese</td>
</tr>
<tr>
<td>Brussels Sprouts</td>
</tr>
<tr>
<td>Dessert Apple</td>
</tr>
<tr>
<td>Dessert Apple</td>
</tr>
<tr>
<td>Ranges</td>
</tr>
</tbody>
</table>

Table 2.3 Summary of results

<table>
<thead>
<tr>
<th>Scenario: 100% Agrochemical Tax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>Calabrese</td>
</tr>
<tr>
<td>Brussels Sprouts</td>
</tr>
<tr>
<td>Dessert Apple</td>
</tr>
<tr>
<td>Dessert Apple</td>
</tr>
<tr>
<td>Dessert Apple</td>
</tr>
<tr>
<td>Ranges</td>
</tr>
</tbody>
</table>
2.4 Workshop questionnaire results

All workshop participants were given two questionnaires to complete, one before the workshop and one afterwards. The pre-workshop questionnaire is shown in Appendix C and the post-workshop questionnaire is shown in Appendix I.

The questions and attendee responses are given, with discussion where appropriate. One attendee did not return the pre-workshop questionnaire, but did return the post-workshop questionnaire, so although there were 33 attendees in all, only 32 responded to some of the questions.

2.4.1 Role/Title of attendees.

<table>
<thead>
<tr>
<th>What is your role/job title?</th>
<th>Brassica</th>
<th>Apples</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm/crops director/manager</td>
<td>10</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Grower</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Growers cooperative manager</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Adviser/consultant</td>
<td>8</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Technologist</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Development engineer</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>21</strong></td>
<td><strong>11</strong></td>
<td><strong>32</strong></td>
</tr>
</tbody>
</table>

Table 2.3 Job role/title of workshop attendees

It can be seen from table 2.3 that all workshop attendees were relevant members of the horticultural industry. Attendees involved in the Brassica industry outnumbered those involved in the apple industry by 2:1, however given the overall similarity in the issues they identified as important, there were sufficient numbers in each sector. The almost equal numbers of growers and advisers (18 and 14) ensured a balance in the different viewpoints of attendees on the issues covered.

Throughout the rest of the questionnaires analysis, the first three groups (Farm/crops director/managers; Growers and Growers cooperative manager) will be referred to as Growers or ‘G’ and the next three groups (Adviser/consultant; Technologist and Development engineer) will be referred to as Advisers or ‘A’.

2.4.2 Reasons for attending and expectations from the workshop

<table>
<thead>
<tr>
<th>What made you decide to attend today’s session?</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>To find out about models and how they can help</td>
<td>11</td>
</tr>
<tr>
<td>To find out about future models</td>
<td>6</td>
</tr>
<tr>
<td>Want to keep abreast of all P&amp;D developments</td>
<td>3</td>
</tr>
<tr>
<td>Interested in relation to ICMS</td>
<td>3</td>
</tr>
<tr>
<td>Believe in value of models</td>
<td>2</td>
</tr>
<tr>
<td>Interest in models</td>
<td>2</td>
</tr>
<tr>
<td>To encourage direction of developments</td>
<td>2</td>
</tr>
<tr>
<td>Commercial interest in weather station develop</td>
<td>1</td>
</tr>
<tr>
<td>Work with models</td>
<td>1</td>
</tr>
<tr>
<td>No answer</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>32</strong></td>
</tr>
</tbody>
</table>

Table 2.4 Reasons given by attendees for attending the workshop
The majority of attendees were looking for information on models, what they were, whether they could help them in their business and what models were being developed for the future. This was the target audience for the workshops, and the fact that the majority of the attendees gave this as their reason for attending seems to indicate that the information sent out accurately reflected the content of the workshops and was pitched at the right level.

Other reasons given for attending fitted within the remit of the workshops, but indicated a more specialised interest in particular aspects of modelling. The areas mentioned could possibly be used in the future for more targeted workshops, such as ‘modelling in relation to ICMS’ or ‘Modelling - the costs’.

### Have you previously used models or model based decision support systems to help with work?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple Growers</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Apple Advisers</td>
<td>4</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Brassica Growers</td>
<td>6</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Brassica Advisers</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>18</strong></td>
<td><strong>14</strong></td>
<td><strong>32</strong></td>
</tr>
</tbody>
</table>

Table 2.6. Attendees who have previously used models in their work

Table 2.6 shows that 18 of the 32 attendees had used models in their work before. Apart from the apple advisers, who had all used models, all the other groups had half the attendees having used models before and half not. However given the small number of apple advisers who attended the workshops, it would not be useful to read anything further into this information.

### Which models have been used and how useful were they?

Of those who had used models before, many had used more than one. They were asked to rate each model they had used on a 4 point rating scale from ‘very useful’ to ‘not at all useful’ and to comment further on why they had given the rating.
<table>
<thead>
<tr>
<th>Model used</th>
<th>No of people</th>
<th>Ratings</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADEM</td>
<td>6</td>
<td>Very Useful -4</td>
<td>Reduced fungicide use with confidence and justification.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Useful -1</td>
<td>Useful in indicating when disease risk is high.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not rated -1</td>
<td>Aid to timing of pesticide application.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All additional information that is available helps in making the correct decisions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Most probably paid for itself in one year.</td>
</tr>
<tr>
<td>PESTMAN</td>
<td>6</td>
<td>Very Useful -4</td>
<td>Confidence and justification in decision making.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Useful -1</td>
<td>Not Interactive enough.</td>
</tr>
<tr>
<td>RImpro</td>
<td>1</td>
<td>Very useful -1</td>
<td>Knowledge that money spent and chemical used is necessary.</td>
</tr>
<tr>
<td>Metos</td>
<td>1</td>
<td>Very useful -1</td>
<td></td>
</tr>
<tr>
<td>Scab prediction</td>
<td>1</td>
<td>Very useful -1</td>
<td>It clarified the risk of scab, thus making my decision making more scientific.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>It made choice of product + timing more accurate.</td>
</tr>
<tr>
<td>Table 2.7. Models used within the apple industry.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model used</th>
<th>No of people</th>
<th>Ratings</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>WellN</td>
<td>5</td>
<td>Very Useful -3</td>
<td>Need more experience</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Useful -3</td>
<td>Time needed to input data excessive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slightly useful -1</td>
<td>Only apply amount of N required</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Has potential and useful to progress ICM</td>
</tr>
<tr>
<td>Cabbage root fly</td>
<td>2</td>
<td>Very useful -1</td>
<td>Enables targeting of crop protection measures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not rated -1</td>
<td></td>
</tr>
<tr>
<td>Carrot fly</td>
<td>3</td>
<td>Very useful -2</td>
<td>Enables targeting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not rated -1</td>
<td>Aid to decision making.</td>
</tr>
<tr>
<td>Pollen beetle</td>
<td>1</td>
<td>Very useful</td>
<td>Targeting of crop protection measures</td>
</tr>
<tr>
<td>Predictions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pest Monitoring</td>
<td>1</td>
<td>Very useful</td>
<td>Pre-empts crop walking</td>
</tr>
<tr>
<td>Iniguide</td>
<td>1</td>
<td>Very useful</td>
<td>Aid to decision making.</td>
</tr>
<tr>
<td>Fentiplan</td>
<td>1</td>
<td>Very useful</td>
<td></td>
</tr>
<tr>
<td>Crop growth and</td>
<td>1</td>
<td>Very useful</td>
<td></td>
</tr>
<tr>
<td>development,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>nutrition and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cauliflower</td>
<td>1</td>
<td>Not at all useful</td>
<td></td>
</tr>
<tr>
<td>maturity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>predictor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pessel, ringspot</td>
<td>1</td>
<td>Useful</td>
<td>But still learning how to use effectively</td>
</tr>
<tr>
<td>and potato</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>blight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spacing</td>
<td>1</td>
<td>Not at all useful</td>
<td>Not user friendly - poor information provided by model.</td>
</tr>
<tr>
<td>(carrots)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Table 2.8 Models used within the Brassica Industry.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
On the whole, attendees previous experiences with models had been positive with 22 ratings of 'very useful' and 4 ratings of 'useful'.

One model was given a rating of slightly useful (1) and 2 models were given a rating of not at all useful. The comments that accompanied these low ratings referred to the lack of user friendliness of the models and excessive amount of data entry required, which are comments on the user interface rather than the science behind the models.

2.4.5 How would you rate the organisation of the workshop?

<table>
<thead>
<tr>
<th>Rating</th>
<th>Kirton</th>
<th>East Malling</th>
<th>Wellesbourne</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>V. Good</td>
<td>7</td>
<td>2</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>Good</td>
<td>9</td>
<td>8</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>Poor</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>V. Poor</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>11</td>
<td>6</td>
<td>33</td>
</tr>
</tbody>
</table>

Table 2.9. Attendees rating of the organisation of the workshops

The participants seemed to feel that the workshop was well organised, in that 32 of the 33 attendees of the workshops rated the organisation as either 'very good' or 'good'.

There is an optimum number of people (between 5 and 9) which allows a sufficient number to spark off discussion whilst also allowing each workshop member to have a say. This rule seems to have been borne out by the attendees own perceptions of the organisation of the workshop, in that the Kirton and Wellesbourne workshops seemed to be rated more highly than the East Mailing workshops, and this may well have been due to the smaller numbers of people who attended each of the East Mailing workshops (4 and 3).

2.4.6 Suggested improvements to the workshop organisation.

<table>
<thead>
<tr>
<th>Suggested improvements to the workshop organisation</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>More time to develop and discuss ideas</td>
<td>5</td>
</tr>
<tr>
<td>More information before attending so they understand what the workshop was about, its aims etc.</td>
<td>4</td>
</tr>
<tr>
<td>Less hypothetical information - difficult to be confident in figures given in session C</td>
<td>3</td>
</tr>
<tr>
<td>Keeping to the timetable better</td>
<td>2</td>
</tr>
<tr>
<td>Larger groups</td>
<td>1</td>
</tr>
<tr>
<td>Mix of growers and advisors</td>
<td>1</td>
</tr>
<tr>
<td>More pre-preparation by participants (maybe ask them to come with figures)</td>
<td>1</td>
</tr>
<tr>
<td>Give out more information on previous surveys or overseas findings for participants to take away</td>
<td>1</td>
</tr>
<tr>
<td>Continue with the workshops to allow growers to express their genuine concerns</td>
<td>1</td>
</tr>
<tr>
<td>Adjust the content for particular groups</td>
<td>1</td>
</tr>
<tr>
<td>Give positive feedback to participants after the workshops</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2.10. Attendees suggested improvements to the workshop organisation
The attendees came up with some valuable suggestions for improvements to the workshops, and comments are given on each of the above suggestions.

2.4.6.1 More time to develop and discuss ideas

This was the most common suggestion and is an indication of the success of the workshops, that the attendees wished to continue with their discussions and develop their ideas more. There was a lot of ground to cover in these workshops, and a lot of information both to collect from attendees and impart to them. However if the workshops had been longer (say a day instead of half a day) it is questionable whether there would have been as many people willing to attend, when workshops such as these are a new and unproved area calling on their time.

However now that some workshops have taken place and their benefits have been proved, maybe longer sessions would be possible in the future. Another option would be to have more focussed workshops, concentrating on particular areas of interest that have been identified during these workshops, thus enabling a deeper discussion of particular issues without increasing the time.

2.4.6.2 More information before attending what the workshop was about, its aims etc.

All attendees received an invitation to attend the workshop detailing what was to take place (see Appendix A). However some attendees thought this was too ambiguous. The use of the word 'models' was questioned, in that with models most people think of 'airfix kits' as one attendee put it. More concrete examples of what is meant by models may have made this clearer.

Given the statements attendees gave before the workshops on their reasons for attending and expectations, most people knew what to expect, although the sessions where information was requested from them may have been less obvious.

For future workshops it would be an improvement to send out a timetable. Also it may be possible to send out some workshop materials (that do not need an explanation as to their use) in advance, but there is a balance between brevity (one side of A4) and appropriate information. Also previous experience in this area is that people do not usually read material before the workshop.

If materials are sent out in advance, it is always prudent to have copies of the same materials available at the workshop for those who have forgotten them.

2.4.6.3 Less hypothetical information

This comment was in connection with the session on the perceived value of weather data to the sector, and given the area being investigated it would have been difficult to be less hypothetical, as we are dealing with the future, and therefore a hypothetical situation. One solution to this may be to experiment with different methods of obtaining the same information to find a method that is more acceptable to workshop attendees, as they did seem to be wary of putting concrete figures to hypothetical situations.

However the activity as it was carried out was of benefit, in that the groups convinced themselves of the value of the weather data and models when working through the scenarios, and were often surprised at the outcome that they themselves arrived at. If they had not worked it out themselves, they may well have questioned the outcome, but as they had worked it out, they were more inclined to accept it.
2.4.6.4 Keeping to the timetable better

This was an aspect of the Kirton workshop particularly, in that discussion both during and after the talk on models by the guest speaker sparked off much interest and discussion, which both the speaker and the workshop attendees were loath to finish. However, timings must be adhered to, as attendees often have other activities booked in the day and further discussion can take place over lunch for those that have the time. Another option would be to increase the time allotted for discussion after the talk, but again, this was an aspect of the full timetable and amount of material to be covered during a half day workshop, and overall the format worked well.

2.4.6.5 Larger groups

This was mentioned by one of the attendees of an East Mailing workshop, and has already been covered previously in that these workshops were smaller than the optimum (5 to 9 is the optimum, whereas the East Mailing workshops had 4 and 3 attendees).

2.4.6.6 Mix of growers and advisors

The separation of growers and advisors into different workshops was deliberate, and was to enable differences between the two groups to be identified. There is a case for mixed workshops, especially if they are more focussed on particular areas of interest. Both formats (mixed and separate) give benefits. Mixed workshops allow ideas to be sparked off between the different groups, whereas separate workshops allow specific groups to air their opinions more freely. Future workshops could take either format, depending on the aims of the workshops and the availability of participants.

2.4.6.7 More pre-preparation by participants (maybe ask them to come with figures)

Previous experience suggests that people do not carry out pre-workshop preparation tasks, however some indication of figures or other information that it may be useful to have with them that is easy for people to collect beforehand could improve discussion, especially for more focussed sessions.

2.4.6.8 Give out more information on previous surveys or overseas findings for participants to take away

Relevant information for people to take away with them after a workshop is always useful. However there was not much previous information available for this workshop. Some ideas for the future could include information on available models and contacts for particular issues.

2.4.6.9 Continue with the workshops to allow growers to express their genuine concerns

A continuation of the workshops would be of value, maybe in differing formats to suit particular occasions (such as shows and conferences), or to focus on particular issues or stages of model development.
2.4.6.10 Adjust the content for particular groups

This set of workshops was generic, in that the same format was used for the advisers as for the growers. More finely tuned workshops could be made available, building on the information received during these workshops, and in being more focussed, could both impart and gain more focussed information. The present workshops served their purpose well, and adjusting the content for different groups would be a continuation of the work already accomplished.

2.4.6.11 Give positive feedback to participants after the workshops

This is always a good idea, to ensure that attendees realise that their input into the workshops was well received and of value, and their views were heard and are being acted upon. This could take the form of a letter of thanks, with a precis of this report attached.

2.4.7 Do you feel you've been given enough information?

<table>
<thead>
<tr>
<th>Rating</th>
<th>Kirton</th>
<th>East Malling</th>
<th>Wellesbourne</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>10</td>
<td>8</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>No</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>No answer</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>11</td>
<td>6</td>
<td>33</td>
</tr>
</tbody>
</table>

Table 2.11. Attendees answers to the question 'were you given enough Information'

2.4.8 What improvements would you suggest?

<table>
<thead>
<tr>
<th>Suggested improvements to the workshop information</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>More information on costs of the technology and use of models</td>
<td>3</td>
</tr>
<tr>
<td>More precise overview how HRI have in mind to develop the modelling scene.</td>
<td>2</td>
</tr>
<tr>
<td>Enough Information for a preliminary discussion, but needs follow-up</td>
<td>2</td>
</tr>
<tr>
<td>Greater awareness that models are for all to use, not just computer and science buffs</td>
<td>1</td>
</tr>
<tr>
<td>Attendees supplying more Information than they were getting</td>
<td>1</td>
</tr>
<tr>
<td>Will be yes if participants able to see summaries of program results and perhaps do repeat workshop to discuss these and associated findings form HUSAT, HRI</td>
<td>1</td>
</tr>
<tr>
<td>Regular updates of new modules available</td>
<td>1</td>
</tr>
<tr>
<td>More scientists to chat to</td>
<td>1</td>
</tr>
<tr>
<td>More technical detail</td>
<td>1</td>
</tr>
<tr>
<td>The talk was excellent</td>
<td>1</td>
</tr>
<tr>
<td>Need to know range of opportunities, and do dummy runs using the models</td>
<td>1</td>
</tr>
<tr>
<td>Possible to improve if discussions were more specific rather than the 'ideal world' scenario</td>
<td>1</td>
</tr>
<tr>
<td>Needed demonstration of a real model</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2.12. Attendees suggested improvements to the information in the workshops
2.4.9 Did you feel you could comment fully?

<table>
<thead>
<tr>
<th>Rating</th>
<th>Kirton</th>
<th>East Mailing</th>
<th>Wellesbourne</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>14</td>
<td>9</td>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>11</td>
<td>6</td>
<td>33</td>
</tr>
</tbody>
</table>

Table 2.13. Attendees answers to the question 'were you given enough information'

Almost all participants felt able to comment fully.

The four participants that did not feel able to comment fully gave their reasons as:
- Needed more time (2)
- Not enough discussion of the role of economies of scale in relation to the uptake of models
- No necessity for commenting fully, not sure the workshop would benefit if everyone did that!

Those who did feel able to comment fully also gave feedback, saying that their awareness of models was improved (2) and from an East Mailing session that the size of the groups encouraged more discussion and feedback, although another attendee from East Mailing commented that more people would have allowed a broader picture to emerge from the discussions.

2.4.10 How do you feel about the usefulness of models and model based decision support systems to your work, based on your experiences in this workshop?

<table>
<thead>
<tr>
<th>Rating</th>
<th>Kirton</th>
<th>East Malling</th>
<th>Wellesbourne</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>V. Positive</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>Positive</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>Negative</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>V. Negative</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>No answer</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>11</td>
<td>6</td>
<td>33</td>
</tr>
</tbody>
</table>

Table 2.14. Attendees rating of the usefulness of models

Thirty of the 33 attendees were either 'very positive' or 'positive' about the usefulness of models based on their experiences in the workshop. Of the remaining three, only one was negative, and the other 2 gave no answer to this question.

The negative response was due to the fact that the attendee felt that the decision support systems as discussed in the workshop were not yet available to the industry.

Comments from those that were very positive or positive to the idea of models are shown in table 2.15 below.

<table>
<thead>
<tr>
<th>Comments on the usefulness of models</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need to see that the models work and build confidence in them</td>
<td>3</td>
</tr>
<tr>
<td>Useful if models become available 'on-line' for a range of crops</td>
<td>1</td>
</tr>
<tr>
<td>Worried about costs and who will pay</td>
<td>1</td>
</tr>
</tbody>
</table>
Industry needs them, as they act as a vital support and link between technical organisations and the growers

Models need to be easy and quick to use

Models support existing practices, but do not replace them

Table 2.15. Attendees comments to accompany their perception of the usefulness of models

2.4.11 What are the main areas of decision making where you think you could make use of models or model based decision support systems?

<table>
<thead>
<tr>
<th>Areas of decision making where models would be most useful</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pest and disease control /prediction</td>
<td>18</td>
</tr>
<tr>
<td>Spray timing</td>
<td>12</td>
</tr>
<tr>
<td>Harvest date / maturity prediction</td>
<td>10</td>
</tr>
<tr>
<td>Spray rates, optimising inputs, reducing use</td>
<td>8</td>
</tr>
<tr>
<td>Spray justification / traceability</td>
<td>6</td>
</tr>
<tr>
<td>Irrigation</td>
<td>5</td>
</tr>
<tr>
<td>Nutrition</td>
<td>5</td>
</tr>
<tr>
<td>Chemical choice</td>
<td>4</td>
</tr>
<tr>
<td>Fertiliser use</td>
<td>3</td>
</tr>
<tr>
<td>Knowing risks of different decisions</td>
<td>2</td>
</tr>
<tr>
<td>Efficiency of previous pesticides</td>
<td>2</td>
</tr>
<tr>
<td>Prioritising work schedules</td>
<td>2</td>
</tr>
<tr>
<td>Quality prediction</td>
<td>2</td>
</tr>
<tr>
<td>Marketing</td>
<td>2</td>
</tr>
<tr>
<td>Storage</td>
<td>2</td>
</tr>
<tr>
<td>To determine when to crop walk</td>
<td>2</td>
</tr>
<tr>
<td>Crop growth models</td>
<td>2</td>
</tr>
<tr>
<td>Safety considerations</td>
<td>1</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1</td>
</tr>
<tr>
<td>Post Harvest treatments</td>
<td>1</td>
</tr>
<tr>
<td>Income changes against input</td>
<td>1</td>
</tr>
<tr>
<td>Planting</td>
<td>1</td>
</tr>
<tr>
<td>Chemical availability</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2.16. Areas of decision making where models would be most useful

2.4.12 Do you think that you would see yourself using model based decision support systems?

<table>
<thead>
<tr>
<th>Rating</th>
<th>Kirton</th>
<th>East Malling</th>
<th>Wellesbourne</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>12</td>
<td>9</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td>Maybe</td>
<td>3</td>
<td>2</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>No</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>n/a</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2.17. Attendees answers to the question 'would you see yourself using models'
2.4.13 What would be the main barriers to using them?

<table>
<thead>
<tr>
<th>Comments on the usefulness of models</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trust/confidence in the models accuracy</td>
<td>3</td>
</tr>
<tr>
<td>Time inputting data to get an answer</td>
<td>1</td>
</tr>
<tr>
<td>Must be user friendly</td>
<td>1</td>
</tr>
<tr>
<td>Cost and cost effectiveness</td>
<td>1</td>
</tr>
<tr>
<td>Training to be able to react to the information from the model</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2.18. Main barriers to using models

2.4.14 Have you any other comments you would like to make about any aspect of today's workshop?

The comments from the pre and post-workshop questionnaires have been combined in the following table.

<table>
<thead>
<tr>
<th>HAVE YOU ANY OTHER COMMENTS YOU WOULD LIKE TO MAKE AT THIS STAGE?</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need for closer liaison between scientist/modeller and users, vital to have input from both sides to make models more valuable</td>
<td>4</td>
</tr>
<tr>
<td>Very well presented, valuable, stimulating and worthwhile day</td>
<td>4</td>
</tr>
<tr>
<td>Invitation could have been clearer, more explanation</td>
<td>2</td>
</tr>
<tr>
<td>Need to see results</td>
<td>2</td>
</tr>
<tr>
<td>Models need to be based on user needs and to be appropriate to the way users want to work for uptake to improve</td>
<td>2</td>
</tr>
<tr>
<td>Insufficient funding going into modelling</td>
<td>1</td>
</tr>
<tr>
<td>Existing models are not always totally accurate</td>
<td>1</td>
</tr>
<tr>
<td>It is important to allow people to use their skills, but to use models as a means of maximising the data available to them</td>
<td>1</td>
</tr>
<tr>
<td>Models need a standard format, minimising inputs required</td>
<td>1</td>
</tr>
<tr>
<td>Pleased to have opportunity to work with others in same field</td>
<td>1</td>
</tr>
<tr>
<td>Session C not thought out enough</td>
<td>1</td>
</tr>
<tr>
<td>Register with TSASIS, and it might be easier to get participants</td>
<td>1</td>
</tr>
<tr>
<td>More time needed</td>
<td>1</td>
</tr>
<tr>
<td>Hands on use of models needed</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2.19 Additional Comments
A financial investment appraisal, discounted over 5 years, was undertaken to assess different approaches to the collection of meteorological data for model based decision support systems.

The following options were considered:

a) **Do-nothing**

The use of regular horticultural practice, with little predictive element, for the production and protection of crops.

3 **On-site Weather Stations**

The provision of separate weather stations for individual farms or fields. In this option the data are manually collected in the field by down-loading to a computer. This is then physically transported to the main office where the predictive computer models are run.

4 **Weather Station network**

The provision of a network of communicating weather stations. These weather stations would be located within a farm or field, feeding data into a central service. The data and/or model outputs would be automatically disseminated to growers and advisors. Weather data from this option could be available to larger UK wide studies. The value of this wider resource has not been assessed and incorporated within this analysis on this occasion.

The costs of each of these options were assessed through discussions with hardware manufacturers and from HRI's experience of the resources required to support and maintain an IT service of this complexity. Costs are divided into one-off costs and ongoing costs. The former include equipment and model purchase and installation. Ongoing costs include hardware maintenance, model support and operational labour costs.

The potential financial benefits of good access to weather data and predictive models was obtained from the grower workshops (Session C) described earlier in this report. The benefits were discussed in the context of the increasing pressure to reduce agrochemical input. Two scenarios were considered:

a) The imposition within two years of a 100% agrochemical tax.

b) The imposition of a mandatory agrochemical reduction programme achieving a 50% reduction of agrochemicals within two years. Consumer pressure might impose similar pressures.

Three crops were considered; Calabrese, Brussels Sprout and Dessert Apple.
3.1.1 Key Assumptions

a) The financial appraisal was assessed over five years. This was considered the maximum life of such equipment.
b) It was suggested by a Weather Station manufacturer that the results of one station were applicable to 100 hectares of vegetables and 20 hectares of fruit. These figures were used for the initial analysis but the validity of such a statement is arguable. The sensitivity of the results to these figures was assessed.
c) In all cases the most conservative estimates of benefits were used in the appraisal.
d) It has been assumed that PC hardware will be required on farm for all options including the Do-Nothing option where it will exist for financial management purposes.

3.1.2 Sensitivity Analyses

The following parameters were considered to assess their effect on the overall outcome of the financial appraisal.

i) The number of hectares of crop over which data from a single weather station can be applied.
ii) The accuracy of the estimates of the gross margin benefit obtained from the workshops.

3.2 Results

Appendix H (Tables H.1 to H.27) provides discounted financial appraisals for each of the three crops in each of the three options when subjected to the two different scenarios. Summary tables are provided giving the Net Present Benefit for each crop over the five year period.

All tables indicate the cost/benefit per hectare of crop with key figures and calculations given at the base of the table.

In all options, scenarios and crops the results indicate a very positive Net Present Benefit when there is easy access to weather data and the necessary predictive models. The analysis indicates that there is little difference between the economics of on-site weather stations and providing a networked service over a five year period. There may, however, be other benefits for the UK horticulture industry as a whole if a fully co-ordinated data service were in place. The benefits of this are not assessed in this report. In reality, providing the appropriate skilled labour force to manage and use an on-farm system may prove to be the limiting factor.

The Do-Nothing option (considered during the workshop when considering limited access to weather data and models) indicates that the gross margin per hectare would decrease substantially under these scenarios if no predictive pest and disease forecasting were available. Clearly this also applies to individual grower holdings that do not adopt these technology when others do.
3.2.1 Sensitivity analyses

3.2.1.1 Number of hectares covered by a single weather station

Appendix tables H.2, H.11 and H.20 show how sensitive the Net Present Benefit is to changes in this parameter for each crop. The results indicate that the benefit may turn negative if the area it is possible to cover by a single weather station proves to be less than 10 hectares. This broad rule seems to be applicable to all three crops considered.

3.2.1.2 Accuracy of gross margin benefits

Throughout this study only the lowest estimates of benefit have been used. In many workshop sessions the projected benefits were higher than those used in the analysis. Appendix tables H.3, H12 and H21 show the effect of a percentage reduction in this lowest estimate.

Typically, reducing the estimate by half still results in a positive Net Present benefit over five years.

The Gross Margin benefits required to break even are:

- Brussels Sprout £23-£27 per hectare (1% of current Gross Margin)
- Calabrese £23-£26 per hectare (>1% of current Gross Margin)
- Dessert Apple £114 per hectare (>3% of current Gross Margin)
4.0 CONCLUSIONS AND RECOMMENDATIONS

The horticultural industry is under increasing pressure to reduce agrochemical input. This financial appraisal has demonstrated that there are substantial, quantifiable financial benefits in implementing pest and disease forecasting models using on-farm weather data. There seems to be little financial advantage in adopting the on-farm approach as opposed to the weather station network approach. However, in reality providing the appropriate skilled labour resource to manage and use an on-farm system may prove to be the limiting factor. The weather data itself can also be used for other areas of on-farm activity (e.g., irrigation planning and crop scheduling), benefits which have not been considered in this assessment.

Good scientific models and new high quality software (e.g., MORPH) make these tools readily available. But, the presence of these tools will be insufficient to ensure their wide uptake and implementation.

There is much work to be done in ensuring that growers are aware of what models are, what they try to achieve and what they mean to their business. The workshops which we have undertaken have indicated that there is a large education process to be undertaken. The concept of workshops, rather than seminars, has been very successful. Participants have developed an understanding of models and their value through their own efforts. The participants believe in the outcome and this has been much more effective than simply presenting all the information in a seminar. The value of the format is supported by the post-workshop questionnaire analysis.

An extensive education process is key to the rapid and effective uptake of this technology. We recommend that:

a) All growers should have the opportunity to attend one of these workshops. It is recommended that workshops should be run throughout the country over the next twelve months.

b) That the content of these workshops should be developed into a module that can be included in the HORIS CD-ROM service. HORIS can incorporate video and interactive material which could be used by growers throughout the country.

The work also highlights the need for a clear understanding of how far data from a single weather station can be effectively interpolated for pest and disease prediction.
APPENDIX A

Invitation and fax/mail reply sheet
WORKSHOPS ON MODELLING IN HORTICULTURE

You are invited to attend a FREE modelling workshop and lunch with experts from Horticultural Research International.

Why is modelling important?
Use of good biological models can greatly enhance the success of your integrated crop, pest or fruit management strategy.

Modelling is the mathematical description of biological processes. Future events can be predicted on the basis of our understanding of the ways in which crops/pests/inputs interact e.g. mathematically describing the effects of the weather on pest development enables us to estimate:
- the current threat given recent past weather conditions;
- the potential threat given estimated weather conditions.
Together with knowledge about pesticide activity, this information can substantially improve the effectiveness of pesticide applications.

Why should I know more about modelling?
Models, contained within user friendly software, are potentially of enormous value to the grower and agronomist alike.

Many such packages, or 'decision support systems' are likely to appear on the market over the next 4-5 years. How will you decide which models, if any, are likely to be of use and, indeed, how can you influence the types of system that are going to be developed? This series of workshops, funded by MAFF and managed by Horticultural Research International, will enable you to do both.

Why should I attend a workshop?
To find out:
- what modelling is and how it might be of use to you
- what models can and can't do for you
- how you can make best use of modelling software

To tell us:
- the problems you think HRI should focus its attention on
- what questions you would like the software to answer
• what benefits you think the technology will have for you

If you would like to attend one of these FREE sessions please fill in and return the reply slip overleaf.
To: Caroline Parker  
Address: HUSAT Research Institute  
The Elms, Elms Grove  
Loughborough, Leics, LE11 1RG  
Tel: 01509 611088  
Fax:  

Yes I would like to attend a FREE modelling workshop and lunch.  
The following dates would be most convenient for me:  

<table>
<thead>
<tr>
<th>Month</th>
<th>Date 1</th>
<th>Date 2</th>
<th>Date 3</th>
<th>Date 4</th>
<th>Date 5</th>
<th>Date 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>?</td>
<td>o</td>
<td></td>
<td>o</td>
<td></td>
<td>o</td>
</tr>
<tr>
<td>January</td>
<td>?</td>
<td>o</td>
<td></td>
<td>o</td>
<td></td>
<td>o</td>
</tr>
<tr>
<td>January</td>
<td>?</td>
<td>o</td>
<td></td>
<td>o</td>
<td></td>
<td>o</td>
</tr>
</tbody>
</table>

If you would like to find out more about the workshops please feel free to contact any of the workshop team members on the numbers below:  

<table>
<thead>
<tr>
<th>Name</th>
<th>Institute</th>
<th>Sector</th>
<th>Contact Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mike Solomon</td>
<td>HRI East Malling</td>
<td>Top fruit sector</td>
<td>01789 470382</td>
</tr>
<tr>
<td>Roy Kennedy</td>
<td>HRI Wellesbourne</td>
<td>Brassica sector</td>
<td>01732 843833</td>
</tr>
<tr>
<td>Steve Lucey</td>
<td>HRI Wellesbourne</td>
<td>IT development</td>
<td>01789 470382</td>
</tr>
<tr>
<td>Caroline Parker</td>
<td>HUSAT Research</td>
<td>Session co-ordinator</td>
<td>01509 611088</td>
</tr>
</tbody>
</table>
APPENDIX B

Overheads used during workshop
• Who are we?
• Aims of the workshop
  – two way technology transfer
  – what are your needs
  – what help can HRI provide
  – what do we mean by models
  – how useful do you think they’ll be to you
  – workshop evaluation
• Timetable
• Feedback - all information is valuable
Timetable

- 9.30 Introduction & questionnaire
- 9.35 Workgroups - needs of sector
- 10.00 Report & summary
- 10.15 Coffee
- 10.25 Where models can help
- 10.30 Modelling - what, how and why
- 11.15 Value to the sector
- 12.15 Summary and questionnaire
- 12.30 Lunch
Session A: Problems & solutions

- What do you think are the most important problems you face:
  - pest/disease/nutrition/irrigation problems
  - impact on quality, costs, environment
  - what questions do you need answers to?
  - where would you like HRI to focus attention?

- Group session

- Report back and summary

- Where models can contribute
Session A: Problems & solutions

- Two groups. Discuss and list the most important questions that you have to answer when making decisions about your crop.
- Do not worry about only covering those questions that you can see could be helped by models, concentrate on getting the main questions down.
- After this we will list and prioritise the questions the groups have identified.
- An explanation of the session is given in the handout in your packs entitled 'Introduction to Session A: Problems and Solutions'.

There are no right or wrong answers
Session B: Modelling

- Aim of session

- Guest speaker
  Roy Kennedy, HRI Wellesbourne

- Questions
Session B: Modelling

- Aim of session
- Guest speaker
  Mike Solomon, HRI East Malling
- Questions
Session C: The value of models

- What value would you place on models which tackled issues of concern to you?
- Discussion groups
  - 2 Groups, 2 future scenarios
  - Discussion, questionnaires
  - Facilitators
- Report back & general discussion
- Summary
Summary

- Summary of workshop discussions
- Final questionnaire
  - technology transfer programme
  - build direct links with industry
- Lunch

Thank you!
APPENDIX C

Pre-workshop questionnaire
Pre-Workshop Questionnaire

Thank you for attending this session today. We hope that you will find it both interesting and informative. This questionnaire is part of our assessment process, to ensure that we are meeting your needs, and to determine what past experience you have with models.

This information is confidential and will be used to help improve future workshops.

What is your role/job title? ............................................................................................................................................

What made you decide to attend today's session? ...................................................................................

Have you previously used models or model based decision support systems to help with work?

Yes □  No □

If Yes, which? ............................................................................................................................................

How useful did you find these tools?

Very Useful □  □  □  Not at all useful □  □  □

Why?

What are your expectations of this session (what do you expect to be shown, to do or to leave with that you did not have before)?

Have you any other comments you would like to make at this stage about any aspects of modelling or today?

THANK YOU
APPENDIX D

Explanation sheet for Session A
Introduction to Session A: Problems and Solutions

During this session, you are asked to consider which are the most important questions that you have to answer when making decisions about your crop; the main problems that you face and would like more scientific input on.

This is to help us identify those areas where HRI can help through the development and use of models.

After you have spent about 20 minutes as a group discussing this, and have selected your areas, we will join these with the areas from the other group, and gain a general agreement about the relative importance to the overall decision making process of each area.

Please feel free to put down areas of concern, even if it is not clear to you how models can help.

There are no right or wrong answers. This is your opportunity to make your areas of concern known, and only you can know what these are.
APPENDIX E

Talk structure for guest speaker
NOTES FOR GUEST LECTURER

General

The objective of the talk is to introduce what models are, how they are developed and highlight their potential benefits and limitations. Practical examples should be used throughout the talk to keep the audience rooted in things they have direct experience of and therefore keep them 'on-board'.

Defining exactly what is meant by a model - complex and simple models.

A model is a mathematical relationship describing the interaction between X parameters on y processes. (Needs a good solid example to turn this into something the audience will relate to.)

- A model can be anything from a complex and complete description of an ecological system, to a grouping of models e.g. models of different parts of a lifecycle linked to models of weather, to a very simple model.
- Sometimes only a small part of the whole system need be modelled to provide useful answers (e.g. focusing in on the critical part of the lifecycle - which are the critical forecasting items in a biological system).
- Sometimes a much larger part of the system needs to be modelled to provide a useful answer (e.g. where the interrelationships between parts of the lifecycle are critical to the solution). A model may exist in parts and yet not be of use because it needs all the parts to be complete.

Confidence in models

- Loss of accuracy that may occur as a result of increasing the complexity of the model.
- Validation, how models may differ in the extent to which they have been validated: number of trials, number of years, geographical validity.

Accuracy of models (probability and distributions)

- Problem of extremes not being as accurate as central values - How far in advance is the model reliable?
- Variation within populations, geographical/spatial variation.

Benefits of models

- Maintaining or increasing quality
- Maintaining or reducing cost Reducing environmental impact
- Use previously elicited problems to show where models could be of benefit and how. Describe how using models fits into an IPM, 1CM, IFP approach.
APPENDIX F

Financial profile sheets used for Session C
TIM WORKSHOPS - SESSION C

The objective of this session is to assess the perceived monetary value of predictive models to the horticultural enterprise.

The group will be divided into two syndicates which will discuss the likely impact of the following scenarios. Each scenario assumes increasing pressure to reduce agrochemical application.

Syndicate A: The imposition within two years of a 100% agrochemical tax (i.e. the cost of agrochemicals will double).

Syndicate B: The imposition of a mandatory agrochemical reduction programme achieving a 50% reduction in the use of agrochemicals within two years.

Each syndicate will be asked to complete two exercises.

Exercise 1: Regular horticultural practice - limited access to predictive models
Each group will be asked to consider which parts of the financial profile will increase and which will decrease by marking the sliding scale. Based on these changes, and using the figures from Nix as their baseline, they will be asked to put figures on the new profile (at today's prices)

Exercise 2: Easy access to predictive models and the necessary meteorological data
The same exercise will be carried out with an additional line under variable costs for funding the use of predictive models and met. data. This will provide an assessment of what they would be prepared to spend on this service.

There will be a facilitator in each group who will encourage elaboration on topics, tape the proceedings and make notes for reporting back to a final discussion session.

Dr S. Lucey
HRI Head of Information Technology
APPENDIX I

Workshop evaluation questionnaire
Workshop Questionnaire

This questionnaire is to enable us to find out what you thought of the workshop.

The information is confidential and will be used to help to improve future workshops, and to give us some feedback on your views.

1. How would you rate the organisation of the workshop?

   Very Poor  [ ]  [ ]  [ ]  Very Good  [ ]

   What improvements would you suggest?

   [ ]

2. Do you feel you've been given enough information?

   Yes  [ ]  No  [ ]

   What improvements would you suggest?

   [ ]

3. Do you think you have been able to comment fully today?

   Yes  [ ]  No  [ ]

   What improvements would have enabled you to comment more fully?

   [ ]

4. How do you feel about the usefulness of models and model based decision support systems to your work, based on your experiences in this workshop?

   Very Negative  [ ]  [ ]  [ ] Very Positive  [ ]
5. Do you think that you would see yourself using model based decision support systems?
   Yes ☐ No ☐ Maybe ☐
   If No or Maybe - what would make you more likely to use it?
   
   
   
   
   
   
   6. Have you any other comments you would like to make about any aspect of today's workshop?
   
   
   
   
   
   
   
   
   THANK YOU
APPENDIX M:
AGMODELS Email Survey: Question and Compiled Responses


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

© by Caroline Parker 1999
BLANK IN ORIGINAL
To: agmodels-1@unl.edu
From: Caroline Parker<c.g.parker@uk.ac.lut>
Subject: Intro & From a Salesperson
Cc:
Bcc:
X-Attachments:

I agree completely. Of course it is important to have the science right,
but I have seen too many models in which the user interface was positively
archaic. This has a direct impact on how much *science* can be done with
the model since wrenching a crummy interface takes *lots* of time

Introduction

I've been following the discussions about the need for friendly user interfaces with some interest and decided this might be a good time to introduce myself.

My name is Caroline Parker and I work for a 'department' within Loughborough University (UK - Midlands) called the HUSAT Research Institute. Our area of interest is the human factors of advanced technology, in all domains. My background is psychology with some AI and computing thrown in for good measure. Prior to joining HUSAT (some 6 years ago) I worked as a 'knowledge engineer'(!) with what was then the UK's National Vegetable Research Station.

OK, what has this to do with Agmodels you might ask. Well to cut a long story short, one of the two agricultural projects I'm currently involved in is looking at the reasons for the lack of uptake of decision support tools (mostly model based) by the grower/farmer population. One of the biggies identified so far is the impenetrability of some user interfaces. Another is the failure to answer the questions the user really wanted answering. Neither of these factors is related to the quality of the underlying science - the user never gets that far. That doesn't mean the robustness of the model in 'the field' is not important, continued use of the program depends on it. Growers and farmers do however seem to be willing to use tools which aren't perfect as long as they have some idea of the confidence they can put in them. Of all the users I have met they are the most accustomed to working with uncertainty (probably from long association with the vagaries of the weather!).

I would be very grateful if anyone out there who has experience of incorporating their models into programs for use by farmers would talk to me and tell me all about it (the good and the bad). In return I'm happy to share any insights I've gained or suggest methods that might prove useful. Please email me directly on c.g.parker@lut.ac.uk & not reply through agmodels as I'm sure that most people will quickly get bored with the discussion!

Caroline
Several points have been raised in response to my original email which I would like to bring back to the group.

1. Use of models by consultants rather than growers

S. Glyde says
>my findings thus far suggest that, indeed in
>Australia at least, and for the time being, adoption of a DSS in
>viticulture will not be undertaken by the growers, rather by
>consultants who will then pass on the information to the growers on
>a fee for service basis.

I can confirm this finding to a certain extent. In both the vegetable and arable domains I have found that the type of decision requiring the support of biological/meteorological models rests most frequently in the hands of the consultants. However this does not mean that some farmers, our fellow agmodellers for example, are not interested in using them. Larger farms, which I am constantly being told will inherit the earth, employ farm managers, highly trained people who are definitely potential users.

The reasons for this lack of uptake by most small/medium sized farmers may be as follows. Farming is time intensive and stressful. Unless the software model is going to offer a substantial increase in profits/cost savings etc. then the time required to learn how to use it, enter the data, analyse the results will not be found. The type of decisions which are supported by models - pest prediction, irrigation schedules, spray management etc. etc. are in areas in which many farmers have limited scientific knowledge. This coupled with the large financial implications of success or failure lead many to seek outside support from specialists (ie consultants). Most will not be willing to trade that accessible and accountable (if costly) human being for the non-prescriptive support of a program - however friendly. (I should say here that I have found no support at all for prescriptive software)

2) Usability vs. usefulness

One of my colleagues has a wonderful overhead which shows a truly beautifully designed interface - every button in the right place - intuitive to use - light on colour etc. but utterly useless because no-one needs the functions it so tastefully provides. How many 'technology transfer' projects have identified the questions which the potential users really need answering. Many, in my experience, have a smart idea which they are trying to find a market for. This is often because of pressure from funding bodies and brings me to my next point.......
3) Who's job is it?
It sounds as if all research institutes in this area are being squeezed financially, and told to get something practical out to the industry to justify their existence. I know this is true in the UK. None of the funding bodies seem to be aware of the extra costs involved in doing this properly and will all be very surprised and dismayed when the 'products' fail. No commercial company would dream of developing a product without adequate market research and pre-launch testing so why are you being asked to do it? While I believe that an understanding of the needs of the industry is essential for anyone writing software for it I also feel that it is unreasonable to expect someone with specialised training in biology to suddenly perform as computer programmer/user interface designer/human factors specialist/market researcher and deliver a scientifically sound, appropriate and usable package for the same price previously paid for delivering learned papers. Ooops a bit of a rant there.

4) Solutions?
Apart from getting lots more funding?!!
Here are a few fairly low cost suggestions based on the user centred design approach with apologies for those who may find them simplistic.
- In lieu of a full scale user requirements survey, ask a small number of potential users to contribute to the development of the system. Inducement, if required, to be a cheap/free version of the software. You might want 2/3 for a start-up 'workshop' to define the questions they need answering. A couple more to check the software at an early stage and perhaps the first lot to use the 'pre-release' version over a longer period of time. Even small numbers of users can help to identify major problems which might prevent software from being used (1).
- Use early consultation to identify potential 'translation problems' with the inputs and outputs to the model. Are you using the same language as the user or focusing on the same parts of the problem? Are your units of measurement the same as those used in the industry (e.g. dry weight is not used by farmers); are the models recommendations based on non-standard experimental equipment; what is the industry language for the yield of that crop? etc. etc.
- Use rapid prototyping/slide shows to present your ideas to users before investing too much in hard code.
- Write 'liaison with users' into future proposals!

Any more?

Summarised list of DSS

Dear Agmodellers
The Christmas break has, at last, given me time to compile the replies to the UK decision support tools question. Apologies for the delay and many thanks to all who contributed. The DSS's are alphabetically listed in two groups, UK and non UK based, plus an extra section on publications and other lists. If any glaring errors or omissions are spotted please let me know and I will produce an update in a month or so.

UK DSS's

ADCOST To calculate the cost of anaerobic digestion.
ADCOST calculates the performance and annual cost of owning and running an anaerobic digester for slurry treatment and methane production. It includes a large number of design and operational variables, all of which may be changed by the user, including the type of waste (e.g. cattle, pigs), characteristics of the waste such as dry matter content, and the use made of the gas. The program is menu driven, and default values are supplied for all of the variables, which can be changed by the user.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk

ADEM
Application: DSS for apple diseases. Commercial product being used 'in anger' by apple and pear farmers and consultants throughout the UK
Also by: D. Morgan, Central Science Laboratory - email: dm00hp@cs1.gov.uk

ARABLE To plan cropping and operations.
A more complex labour and machinery planning program than PLAN with an extensive crop and operation database. The model optimises the cropping, labour and machinery, producing a workplan which maximises farm profit. The user specifies the crops to consider, then the program suggests operations and appropriate work rates, automatically adjusted for machine size, crop yield and soil type, which the user can accept or adjust. The model selects the optimum crop rotation based on specified rotational penalties. The expected available workable hours throughout the year are derived from soil type and annual rainfall. The model uses the same method as COST to determine an annual cost for machinery. The report section gives comprehensive details of the cropping and labour and machinery use including a workplan and a use profile.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk

BROCCOLI
A maturity prediction system for 6 varieties of Broccoli using meteorological and crop data. The model helps to fill gaps in supply by predicting fluctuations in availability.
Available from: Dr D. Wurr. HRI Wellesbourne, Warwicks, CV35 9EF, UK or from the Horticultural Development Council.
Sent by: HRI Wellesbourne

COST To calculate the annual cost of farm machinery.
The annual cost is directly comparable with other annual cash flows, such as corn sales or contract charges. It includes resale value, repairs, interest and inflation.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk

COW To evaluate dairy cow feeding systems.
COW performs an economic comparison of two dairy cow feeding systems specified by the user. A feeding system is defined by 29 factors, including the feeding values of forage and concentrates; the prices of milk, fertiliser and concentrates; and the amount of dry matter, energy and labour required by the cows.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk

DRIER To calculate the cost of high temperature drying.
DRIER calculates the cost of owning and operating a high temperature grain drier including capital cost, inflation, interest, fuel efficiency and the throughput, input and output moisture content of the grain.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk

FUNGIC To simulate a cereal crop.
A crop growth simulation which demonstrates the effect of applications of nitrogen and fungicides to a cereal crop on the progress of disease and the final yield. The user specifies his situation, including soil type, crop and sowing date, and can then decide interactively when to apply nitrogen and fungicides.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk

HARV To calculate the cost of combine harvesting.
HARV calculates the overall cost of combining a given area of cereals including the cost of machinery, threshing loss and shedding loss. The user can specify one or more combines, optionally including the use of a contractor and the program also calculates the optimum size(s) of combine and speeds for the situation.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk
HARDRY  To calculate the cost of combine harvesting and high temperature drying.
HARDRY simulates the harvesting and drying of a sequence of combinable crops. The
user specifies system details such as harvester and header type, size and speed. The
model calculates the average cost over 10 years including machinery, threshing and
shedding losses and drying costs.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute,
Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk

NCYCLE
It is a simple tool for balancing nitrogen inputs and outputs to a farm on an annual basis,
and to look at the results. Very simple, pretty friendly, colourful.
Available from: Drs David Scholefield and David Lockyer at IGER North Wyke
Research Station, Okehampton, Devon, EX20 2SB, UK, Tel +44 837 82558, Fax +44
837 82139..
Sent by: Dr Simon JR Woodward, email: woodwards@agresearch.cri.nz

NEARAM  To simulate near ambient temperature drying.
NEARAM simulates the drying of grain in a deep bed at a near ambient air temperature,
and provides a colour graphical display showing the progress of drying within the grain
bed. Grain spoilage is calculated to determine whether drying is successful. The user
specifies the initial grain conditions and may try alternative control strategies including
the use of a modulated heater or a dehumidifier to attempt to dry the grain successfully.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute,
Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk

PEST-MAN
Application: DSS for top fruit insect pest management. Commercial product being
used 'in anger' by apple and pear farmers and consultants throughout the UK
Also by: D. Morgan, Central Science Laboratory - email: dm00hp@csl.gov.uk

PLAN  To plan the use of labour and machinery.
PLAN calculates the least cost system of labour and machinery to complete the
operations specified by the user on his crops. It includes crop areas, work rates, hours
available for work, critical machines and penalties for not completing the operation at the
optimum time. A utility program is also supplied which allows the user to add new crops
and operations to the database, in order to simulate his particular farm situation. The user
specifies the crop sequences for which he wishes to plan the labour, and the program
reads the details of the operations needed from the database. Changes to the operations
can then be made to calculate the saving in labour and cost, which can be compared with
the cost of making the change. The program produces a printed chart of the least cost
work plan.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute,
Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk
SPACING
A commercial DSS which predicts the seeding rate in each row of carrot or red beet crops to maximise the yield in marketable grade sizes.
Available from: Dr Lawrence Benjamin. HRI Wellesbourne, Warwicks, CV35 9EF, UK (email: LAURENCE.BENJAMIN@bbsrc.ac.uk) or from the Horticultural Development Council.
Sent by: HRI Wellesbourne

SPRAY To calculate the effect of logistics on spraying work rate.
SPRAY calculates the work rate achieved when spraying a given field using a particular spraying system due to the logistics of getting water to the field. The 25 variables taken into account include field size and distance from farm, application rate, boom size, tank capacity, filling time, and use or not of the bowser.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk

TRAC To predict tractor work rates.
TRAC predicts the work rate of a tractor and draught implement (mouldboard plough, chisel plough or subsoiler) in user-specific soil conditions and demonstrates the effect of tractor power, number of driven wheels, tyre size, ballast and implement size.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk

TRANS To predict the effect of transport on system work rate.
TRANS predicts the effect of transport on the overall work rate of farm vehicles undertaking a variety of operations. The user can either specify his own field sizes and distances, or use standard data from 44 farms. For harvesting operations it predicts the idle time of the harvester due to the number of transport vehicles. For application operations it predicts the overall work rate due to returning to the farmstead to fill up the applicator.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk

WATER To compare irrigation strategies.
WATER is a daily simulation of soil moisture and plant growth for horticultural crops, which calculates the crop yield and water used due to following an irrigation strategy with up to 8 years historical weather data. The user specifies details of the crop including root depth, sowing and harvesting dates, details of the soil type, and details of the irrigation strategy. The strategy can be a combination of dates and deficit irrigation.
Available from: Mathematics and Decision Systems Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS
Sent by: Eric Audsley - email: eric.audsley@bbsrc.ac.uk
WELLN
A commercial DSS for predicting the amount of nitrogen fertiliser required to maximise a
variety of crop yields.
Available from: Dr Clive Rahn, HRI Wellesbourne, Warwicks, CV35 9EF, UK or from
the Horticultural Development Council.
Sent by: HRI Wellesbourne

NON-UK BASED MODELS

BOVISION
Application: A specialist decision support tool tailored to New Zealand beef finishing
operations. It allows reconciliation of stock age classes, buying and selling, mating and
feed planning, as well as performing economic analyses.
Available from: AgResearch Software, Whatawhata Research Centre, Private Bag 3090,
Hamilton, New Zealand, Tel +64 7 829 8016, Fax +64 7 829 8871
Sent by: Dr Simon J R Woodward, email: woodwards@agresearch.cri.nz

CALEX/Cotton
Available from: IPM Publications, University of California, Davis CA 95616 USA, 25
dollars.
Sent by: Richard E. Plant - Email: replant@ucdavis.edu

CALEX/Rice
Available from: IPM Publications, University of California, Davis CA 95616 USA, 25
dollars.
Sent by: Richard E. Plant - Email: replant@ucdavis.edu

CropSys
U of Hawaii
Sent by: Karl Schnelle, DowElanco - email: kschnelle@dowelanco.com

DSSAT
U of Georgia, etc
Sent by: Karl Schnelle, DowElanco - email: kschnelle@dowelanco.com

FARM TRACKER
Farm status monitoring software. c/- Barry Butler, Plant Science Dept, Massey
University, Palmerston North, NZ
Sent by: Dr Simon J R Woodward, email: woodwards@agresearch.cri.nz

GOSSYM/COMAX
USDA, cotton
Sent by: Karl Schnelle, DowElanco - email: kschnelle@dowelanco.com
GRASIM
Grazing simulation model
first international symposium on mathematical modeling and simulation in agricultural
and biological industries, sponsored by IMACS/IFAC,
May 9-12, 1995, Brussels, Belgium.
Sent by: Rabi Mohtar - email: RHM8@PSUVM.PSU.EDU

GRAZFEED
Also from CSIRO and part of a larger system, Grazplan. Grazfeed is a sheep/wool/beef
production model based on the Standing Committee on Agriculture’s 1990 report,
Feeding Standards for Australian Livestock-Ruminants. It is best considered as a
computerised version of your MAFF/ARC tables/equations. Much of the data is based on
NRC/ARC data but updated from Australian trials involving temperate pasture species.
There is also an economics component, costs of supplementing etc are able to be
examined. The major authors are Freer, Donnelly and Moore and I think they have a
series of papers submitted to Ag Systems, otherwise no published info to my knowledge.
Sent by: Wayne Hall, QLD DPI - email: wayneh@cocaine.ind.dpi.qld.gov.au

HERD-ECON
A dynamic flock/herd population and economics decision support system. Biological rates
e.g. lambing need to be inputted along with costs and prices. The program allows different
management decisions to be examined in terms of short and long term economic effects.
This system is part of a larger system of DSS’s called Rangepack. The two developers
are Barney Foran and Mark Stafford-Smith of CSIRO, Alice Springs. Barney may have
moved on to Canberra. There are some conference publications around.
Sent by: Wayne Hall, QLD DPI - email: wayneh@cocaine.ind.dpi.qld.gov.au

Organic Matter Calculator and N Calculator
Hand held slide rules more for “one-foot-in-the-field” use. The N calculator would need
quite a bit of re-calibration out of southern Australia.
Sent by: Peter Grace, University of Adelaide - email: gracep@adl.soils.csiro.au

OUTLOOK
Designed to help New Zealand farmers with planning long term fertiliser policy, by
predicting the soil nutrient carryover from year to year and comparing economic returns
from contrasting fertiliser strategies. Currently only phosphate is considered, but the
upgraded version due to be released in February 1996 will incorporate sulphur dynamics
as well. The new version will be in Windows.
Available from: Soil Fertility Service, Ruakura Research Centre, Private Bag 3123,
Hamilton, New Zealand, Tel +64 7 838 5920, Fax +64 7 838 5160
Sent by: Dr Simon J R Woodward, email: woodwards@agresearch.cri.nz

RANGEPACK
A suite of 4 farm management packages developed in Australia, highly regarded.
Sent by: Dr Simon J R Woodward, email: woodwards@agresearch.cri.nz
SIMPOTATO
Application: For scheduling water and nitrogen applications and for monitoring plant uptake and soil N status. Deepdrainage and NO3 leaching are also model outputs.
Sent by: Tom Hodges, Cropping Systems Modeler
e-mail: thodges@beta.tricity.wsu.edu

SOCRATES
Looks at changes in soil organic C in farming systems. It is an educational tool for use by extension agents, students and some farmers. SOCRATES has a parameter editor.
Sent by: Peter Grace, University of Adelaide - e-mail: gracep@adl.soils.csiro.au

STOCKPOL
Application: A major tool for stock planning and feed budgeting with multiple stock classes. It is based on dynamic pasture and animal models. This is the flagship and is being used extensively throughout New Zealand, including as an educational aid in farm planning.
Available from: AgResearch Software, Whatawhata Research Centre, Private Bag 3090, Hamilton, New Zealand, Tel +64 7 829 8016, Fax +64 7 829 8871
Sent by: Dr Simon J R Woodward, e-mail: woodwards@agresearch.cri.nz

TOPFLITE
Application: Helps farmers in New Zealand to plan the timing of shearing to achieve certain wool weight and quality goals, and examines factors affecting wool quality and feed requirements.
Available from: AgResearch Software, Whatawhata Research Centre, Private Bag 3090, Hamilton, New Zealand, Tel +64 7 829 8016, Fax +64 7 829 8871
Sent by: Dr Simon J R Woodward, e-mail: woodwards@agresearch.cri.nz

UDDER
Specifically for Dairy Operations in NZ, developed at Dairy Research Corporation, Private Bag, Hamilton, NZ.
Sent by: Dr Simon J R Woodward, e-mail: woodwards@agresearch.cri.nz

VAXTLINE (Plantline)
Computer based decision support system the principles of which could be applied anywhere.
Available from: Vastsvenska Lantman (West Swedish Farmers Co-operative, VL)
Sent by: Mats Soderstrom, Gothenburg University - e-mail: MATSS@gig.gu.se

Publications and other lists
From AFRC Institute of Engineering Research
Wrest Park, Silsoe
Bedford MK45 4HS

A register of mathematical/computer models used in agricultural research and extension in the UK. The 160 models described are arranged by subject and purpose.

Sent by: Karl Schnelle, DowElanco - email: kschnelle@dowelanco.com

Also by: D. Morgan, Central Science Laboratory - email: dm00hp@csl.gov.uk


Sent by: Peter Goodall, Kearney Ag Center - email: IPMPBG@UCKAC.EDU

A couple of years ago Ray Griggs compiled a basic list of some 30 non-point source simulation models into a simple AI tool called MOD-C-LECT. It is available thru ftp brcsun0.tamu.edu, anonymous login, your email address as the password and the path pub/preap/modclect

Sent by: Ray H. Griggs - email griggs@brcsun0.tamu.edu

The CAMASE concerted action is compiling a list of crop and farm models and is about to start on those produced in the UK. Version 1 of the register of agro-ecosystem models covers those produced in the Netherlands. DSS models might come within the remit of the publication. More information later.

Sent by: Dr G. Russell, University of Edinburgh - email: GRUSSELL@srv0.bio.ed.ac.uk

Also Pennsylvania State University (contact: Ed Rajotte) who have a number of DSS tools.

Sent by: Richard E. Plant - Email: replant@ucdavis.edu

Wayne Meyer of CSIRO Water Resources (wayne@griffith.dwr.csiro.au) has been actively involved in DSS’s for irrigated cropping and is worth contacting.

Sent by: Peter Grace, University of Adelaide - email: gracep@adl.soils.csiro.au

Also: http://dino.wiz.uni-kassel.de/model_db/mdb/dssat.html
It contains info about various models, the common thread is an ecological aspect. It doesn’t have everything, but if you want a comprehensive list, this should be on it.

Sent by: Will Stites, Central Wisconsin Groundwater Center - email wstites@fsmail.uwsp.edu
Caroline wrote:

>Dear Dr Laurenson

>I'm looking for examples of successful DSS to quote in a paper I'm writing for the UK based journal Farm Management (the paper examines the reasons for past DSS failures and extols the virtues of a more user friendly approach). I became aware of your work with Orchard 2000 when you paid a visit to the DESSAC team in the UK a few years ago and am very interested in the system.

>As a human factors practitioner, my particular interest is in the 'user centred' nature of your design process and the impact you feel this has had on the interest in, and uptake of, the system. I wondered if you would be able to point me in the direction of any hard data on what percentage of the potential market has adopted Orchard 2000 - or failing that some guesstimate of the numbers involved.

>I will, of course, be very happy to send you a copy of the paper.

>Regards

>Caroline

>------------------------------------------------------
>c.g.parker@lboro.ac.uk

Caroline

Thanks for your e-mail, and interest in Orchard 2000. I'm on holiday in Auckland at present, enroute to spending a couple of years in Japan, but have forwarded a copy of this reply to my colleague Jack McKenzie in case he has anything further to add. Jack is now looking after Orchard 2000.

The market size for Orchard 2000 is a little difficult to define. If you can get hold of the publication "Key Statistics" from the Statics Dept of New Zealand, you may be able to get some up to date numbers of growers. I understand there are about 1300 apple growers in New Zealand, and there are around 1000 grape growers, and perhaps 3000 kiwifruit growers.

We have about 90 paying clients in New Zealand. In addition there are around 30 users of the software among our staff of 500. We don't enquire of clients which crops they grow, but I would guess around 50 of those are apple growers, using our apple scab software Spot Check. However, taking these user numbers at face value may be misleading. Two of the largest apple growers in New Zealand are among our clients. Others include three agrichemical retailers in the principal apple growing regions of New Zealand (Hawkes Bay and Nelson), who routinely pass information from the software on to their clients. Terry Stewart (T.M.Stewart@massey.ac.nz I think) of Massey University found that agrichemical reps in New Zealand were the key advisers of apple growers in
terms of pest and disease management (possibly published in Proceedings of NZ Plant Protection Society a couple of years ago).

There is also a company which faxes weather risk information to around 120 growers, and a group of 30 or so growers in Central Otago who receive daily risk faxes. What I'm suggesting is that information derived from the software has a reasonably high uptake level, particularly in terms of the area of apples produced "under the influence". We haven't been successful in finding ways to capture revenue from all these users, but we're working on it.

For the record, users of our software pay around 70 pounds a year for the software, and from 70-100 pounds a year for access to a weather station. Times have been fairly difficult for New Zealand apple growers for the past three seasons (the time when we hoped sales would take off) and a number of our past clients have been forced out of business as the industry has declined.

In Australia one company using our software to provide a service to growers charges around 300 pounds per season for a daily fax service. The number of users in Australia has increased in the last year or so to around 10.

The modular approach we have taken to software development, and the mix of tools currently available reflects:
- that we have worked on a reasonably limited budget, and had to pick and choose where we thought we could get the most rapid pay back - an organisational culture which in the past (1992-1997) looked on financial tools as outside its domain.
- our decision to focus on the New Zealand apple industry as our major client group (we are now moving into grapes for example) - the limited range of science that was suitable for incorporation in grower tools (as opposed to models for enhancing scientific understanding)

I'd note in respect of the latter point that software developed to help scientists understand biological processes is rarely suitable for grower use. One tool is concerned with flexibility and analysis, whereas the other needs to be easy to use as part of a management routine. These two forces are diametrically opposed. The ideal scientists tool would have a knob for every variable, whereas the ideal grower tool would have none!

I'm sorry I don't have more useful numbers for you, or access to my collections of papers for more definitive references. If any of the above is useful I'd gladly expand, but Jack probably has more of the numbers that you need on hand.

Happy New Year

Matthew Laurenson
APPENDIX N:
GRIME Internal Discussion Document: Generic Tasks for Horticultural DSS


By
Caroline Parker

Submitted in partial fulfilment of the requirements for the award of PhD of Loughborough University

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Here are some features of the decision process in horticulture gleaned from the discussions with growers and advisers so far. The ideas are in note form under the headings: models, tasks and other. Other covers a multitude of things! I have separated out the observations into grower/consultant and scientist headings. Finally an idea on the modular approach to interface integration with HIPPO.

GROWERS & CONSULTANTS

Models
Growers have models of the following in their heads which they use when making decisions:
- model of the year task cycle (Tools to support- optimix,farmplan, etc)
- model of the crop location (Tools to support- optimix,farmplan, etc)
- model of the profit/cost ratio (No tools to support – DSS could help)

Tasks
These are easier to define as questions

DSS type questions
- when is harvest likely
- when should I plant
- when will seeds emerge
- when should I irrigate
- when to spray - fert, insect, fungicide
- how much of x to use to get max benefits, min cost
- what will the crop look like if I do this
- how can I get the crop to look like this

Map based questions
- what the most efficient way to move between a,b,c,d and e
- how should I plan rotation

Growers and Consultants use 2 methods to answer DSS type questions
1) work back from market requirement get plan
   - when should I plant
   - when will seeds emerge
     - how can I get the crop to look like this all vars (what fert/variety??/irrig./) v
     vague probability best for experts.
   - how can I get the crop to look like this using this machinery (spacing)
   - how much of x to use to get max benefits, min cost
2) work forward from current status get prediction
   - when is harvest likely
   - when will seeds emerge
   - when should I irrigate
   - when to spray - fert, insect, fungicide
   - how much of x to use to get max benefits, min cost
   - what will the crop look like if I do this

They are highly market driven.

Key inputs to decision processes
- crop type, variety
- desired size, shape
- met data, average and local
- spray type, machinery type
- current status of crop/pest/disease
- market prices of crop/fert/spray
- records of previous sprays (input or stored)
- planting date, harvest date
- field/plot location/name
- soil type
- field specific attributes - wetter/colder etc
- customer/client name
- notes

Key outputs
- graphical output of plant/insect/fung/pest/disease progress over growing units of time (these need to match individual growers).
- graphical display of effect of different spray/irrigation applications.
- method of indicating optimum time to pick/spray given parameters with upper and lower confidence limits.
- Poss. of displaying more than one at a time or of overlaying different choices.
- ? tabular output showing optimum plus upper and lower limits.

Other interface features
Some explanation of reasons for choice
ie given that there is expected to be 2” rainfall and 5hrs average sunlight etc

Interface to or have spray record routine so that grower can press 'spray' and system will prompt for info to fill in form - print out right number of copies and file system copy in spray folder. For small fee could adapt to fit exact current shape/style

Access to field/plot records
Scientists

Models

- model of the object lifecycle with inputs outputs relationships plus met data = results can check

Tasks

- develop model
- first stage examination of relationships by biologist
- use to describe relationships to biometrician
- use mathematical descriptions to generate predictions
- test model against data (this either has to be very easily done in another package or done in HIPPO)
- bring parts of model together
- output code in form that user can use.

Must be annotateable
Must be checkable

Has to make sense to biologists - simple lifecycle, biometrician - underlying math relationships.

Possible modular approach
If we can specify a number of core model types with fairly standard input/output requirements then could visualise a system which can compile models with standard interface features. The system requests the input/output names from the scientist and the names of any associated files (or can it just assume those) then compiles so that the bits will fit into file headings and will prompt the right input and present the right output - incremental so that the use could have several modules in situ.