The M&WNZ ForageMaster®: Decision Support for Forage Selection

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EXTENDED ABSTRACT

Matching forage supply to demand is a key issue in efficient pastoral production and one of the few tools that sheep and beef farmers have to manipulate supply is the mix of forages on their farm. With an extensive range of species and cultivars available, the problem of choosing which forage to sow can be daunting. This paper describes the planning, implementation, and release of ForageMaster®, a decision support and learning tool developed under a Meat & Wool New Zealand (M&WNZ) programme to provide advice on forage selection.

Forage selection is a multi-criteria decision, using information relating to potential performance, ability to withstand any pests and diseases, and the function that the farmer wants the forage to perform. The ELECTRE III outranking method was selected as the core of the decision model. The inputs required by the decision model were lists of the criteria important to the user and the relative weights of these criteria. Using the ELECTRE III method, it was also possible to show users which of their criteria influenced the recommended forages and to see why some forages were excluded from consideration. This allowed users the opportunity to reflect on the criterion weightings that they selected and to see why the software selected particular forages.

Forage selection decisions are made infrequently, so it was essential that the user interface for ForageMaster® be intuitive, that it requested information in a form that was readily available to users, and that it was robust. Considerable effort went into the design of the interface, and the design was tested with mentor groups to ensure that farmers found the information to be readily available to them and easy to understand. An example input screen is given in Figure 1.

Software tools released without support are unlikely to be used to any significant degree. Over fifty workshops were therefore held throughout the country to discuss the many aspects of forage selection, establishment, and management, and help farmers learn to use the software in their decision processes. The workshops were designed using the principles of the AgCelerate® learning programme.

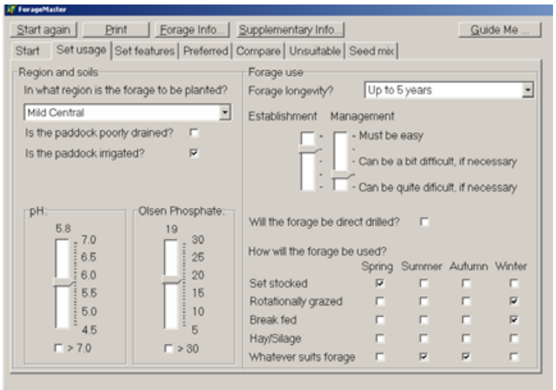

Figure 1. The first, of two, input screens.

While it is too early yet to state that ForageMaster® has been totally successful in its ultimate aim, to improve on-farm productivity, the degree of farmer interest in attending workshops using ForageMaster® suggests that the software will be well-used. The key steps in producing the ForageMaster® software were that:

- it was ensured that the objective of the software aligned well with what farmer mentor groups wanted;
- the software had a very intuitive interface;
- the recommendations made by the software were presented in a manner that allowed the user to easily discover the rationale for the recommendations, and so build trust in the software;
- the release of the software was accompanied by a large number of workshops, which the farmers had to attend if they wanted to get a copy of the software.

Progress with ForageMaster® will be monitored, but at this stage it seems this has been a successful formula and one that is likely to be followed in development of future tools.

1. INTRODUCTION

Efficient production and utilisation of forage underpins New Zealand's pastoral industries. On most sheep and beef farms there is limited capacity to move feed surpluses to times of deficit using fodder conservation, so matching supply to demand is proportionately more important than on other farms.

There are many different forages available to supply quality feed at differing times of the year. Farmers can therefore manipulate the feed supply through careful choice of the range of forage types on their farms. However, with an enormous range of species and cultivars available, farmers are presented with a dauntingly difficult decision (Brown and Green 2003) despite (or perhaps because of) the wealth of information that is available to them. Although technical information on forages is readily available (e.g. Stewart and Charlton 2003), information that is targeted at farmers often comes from seed companies and is not perceived as being independent advice. Although the benefits of quality forage supplied at the right time are high, the cost of planting a forage crop or regrassing a pasture can be significant, so it is important that the right choices are made.

This paper describes the planning, implementation, and release of ForageMaster®, a decision support software (DSS) tool developed in a Meat & Wool New Zealand (M&WNZ) research programme. The objective of the research programme was to provide farmers with an objective tool with which to plan forage on their farms.

2. THE PRELIMINARIES: SETTING THE OBJECTIVE AND SCOPE (AND LISTENTING TO THE USERS)

McCown (2002) pointed out that many of the agricultural decision support systems produced have not been used by their intended users. One way to avoid this fate is to firstly ensure that the DSS was wanted by the intended audience.

The initial project funded by M&WNZ was to develop a tool to optimise the mix of forages on a farm, based on criteria to be set by users. Given appropriate input data, this tool would recommend, for instance, that x% of a farm should be sown in a mix of forage A and forage B, y% should be sown in forage C, and z% in forage D. In preparation for the project, consultation with farmers (through a series of workshops in the North and South Islands), had identified that such a tool was high among their priorities. In addition, as part of the project management process, three farmer mentor groups were set up to guide the project and provide feedback to the development team. As the project got underway, more detailed consultation was undertaken with the mentor groups. These groups indicated that while the optimisation of the forages on the farm was a high priority, farmers felt they did not have sufficient accurate, up to date, and independent information on which forages to plant, and that this was an important issue to address before any optimisation could take place.

The direction of the project was therefore changed so that it would meet the identified need for a "forage selection" tool as opposed to the "forage optimisation" tool that had initially been funded by the M&WNZ. The outputs of the project were renegotiated to reflect the opinions of the mentor groups. The renegotiated project was to produce a DSS that would provide appropriately packaged information from which farmers could:

- decide which forage types and species to plant,
- access basic descriptive information about the forages, and
- obtain advice on appropriate seed mixes.

Although it is an important part of their farming operation, farmers make decisions about which forages to plant relatively infrequently. Therefore it was important that the DSS was intuitive to use, that all information requested of the user was readily available, and that the DSS accepted the information in a format that was easily understood by the infrequent user. It was also important that the DSS provided accurate and sensible information and that it allowed farmers to find out why given forages were recommended or rejected. The ability to 'see' the reasoning behind the recommendations was identified as important in helping farmers develop trust in the tool. Finally, just as a wide range of forages is available there are also wide ranges of preferences, conditions, and requirements for the forages and the tool had to be able to make sensible recommendations in the face of this diversity.

3. IMPLEMENTATION: ASKING THE RIGHT QUESTIONS AND GETTING THE RIGHT ANSWERS

Early in the development of ForageMaster® it was clear that the issue was not a lack of information, but rather that the information had not been collated in a form that allowed ready comparison between candidate forages. Given the challenges faced by any collator of data on the species and cultivars available, as well as the range of different farmer requirements for the forages, this was understandable. Forages have been developed to meet a variety of needs, cope with a range of pests and diseases, environmental and soil conditions, and be suitable for a range of uses. While basic information about suitability exists, the diversity of uses and conditions presents a significant challenge to presenting the information in an accessible and coherent manner.

The objective of ForageMaster® was to recommend the most suitable forage mixes given a farmer's requirements. Often decisions like these are guided by some sort of decision tree based on layers of requirements and needs. Such trees can quickly become cumbersome if they have to cover many different combinations of conditions (e.g. Romera *et al.* 2004). Another, problem is that all choices in decision trees are 'hard', or yes/no, decisions. While some of the choices in selecting forages are suitable for hard decisions, e.g. "will white clover grow in a soil of pH 5.6?", others are more preference than decision, e.g. "must the forage be easy to manage?" While it is appropriate to use a hard decision to remove a forage from further consideration if it will not grow under a given soil, environment, or intended use, the results from preference decisions cannot be so clear-cut.

3.1. The Decision Making Method

The foregoing considerations led to the view that forage selection was a multi-criteria decision that would use information relating to the potential performance of the forage in a particular farm environment, how the forage was likely to withstand any pests and diseases present on the farm, and the function that the farmer wanted the forage to perform. There are many multi-criteria decision making techniques (see for example Belton and Stewart 2002), and the selection of an appropriate technique requires consideration of the properties of a given decision and the factors to be included in that decision. Many factors were considered when choosing the decision-making method but the most important were that:

- there were many possible criteria;
- not all criteria would be equally important and some might not be important at all to some farmers;
- the decision was to be made by an individual, rather than a group;
- there were many alternatives and they were discrete (i.e. the output would be a forage or a list of forages, rather than a value or values on a continuous scale);
- some of the selection criteria were subjective (and therefore had to be scored by the user rather than measured);
- there would be no interactive involvement with the user beyond the DSS itself, so there would be no opportunity to customise the decision-making approach to suit needs that the user might express during the process..

Given these factors, a multi-attribute decision making (MADM) method was preferred to a multi-objective decision making method. Several MADM techniques were considered and the ELECTRE III outranking method developed by Roy (1991) and further described by Buchanan *et al.* (1999), was selected, as described by Finlayson *et al.* (2004).

The first step in applying the ELECTRE III algorithm was to score all the forages against all the attributes or criteria that the user has set. Different scales were used for different attributes. For example, the ability withstand waterlogged soils was scored on a 1-6 scale while the potential of the species for production in summer was on a 0-100 scale. Other attributes were used to remove unsuitable forages from consideration, for example annual grasses are not suitable for set stocking, and were scored on a 0/1 (no/yes) scale. Concordance and discordance with the assertion that any species was preferred to another were calculated for all attributes within each species combination using threshold values indicating veto (definitely worse), indifference, weak preference, or strong preference for one species over another. The concordance and discordance values were then combined with weights indicating the user's requirements of the forage. Using this method, each species was compared with all other species to calculate the final ranking. Note that the result of this method did not indicate how much more one forage was preferred to another.

An important advantage of the ELECTRE III method was that the indifference and preference thresholds were suited to decisions where both the information base and the input data were uncertain or imprecise. The method also allowed the user to weight their preferences for the forage without the method being overly sensitive to the absolute values of the weights selected. The method further allowed the user to compare pairs of alternatives to identify the criteria on which the preferred alternative outperformed the other. This comparison helped the user identify why the recommendations were made. More information on the implementation of the ELECTRE III algorithm in ForageMaster® can be found in Finlayson *et al.* (2004).

The inputs required of the user by ELECTRE III were the list of criteria that were important to the user and the weightings of those criteria. As these related directly to the function that the farmer wanted the forage to fulfil on their farm, supplying the required criteria was relatively simple. Using the ELECTRE III method, it was also possible to show users what factors in their criteria setting influenced the recommended forages and to see why some forages were excluded from further consideration. This allowed users the opportunity to reflect on the criteria weightings that they set.

3.2. The Information Base

The information needed to run the ELECTRE III method included:

- a list of criteria against which the forages would be assessed (e.g. ability to produce fodder in summer, resistance to grass grub, etc.),
- the rankings for each of the forage species and cultivars against those criteria, and
- the individual farmer's preferences or indifferences to each of the criteria.

The preferences were entered by the user at run-time while the list of criteria, and the forage rankings against those criteria, were part of the database included within ForageMaster® as tab-delimited text files. The criteria were developed in collaboration with the farmer mentor groups and the use of tab-delimited text files made it easy for the non-programmers in the development team to edit the files as the criteria were refined and as additional forages were added to the original set of alternatives.

3.3. The User Interface

Because forage selection decisions are made on an infrequent basis it was essential that the user interface for ForageMaster® was intuitive, requested information in a form that was readily available to users, and was robust. Considerable effort went into the design of the interface, and in testing the design with the mentor groups, to ensure that farmers found that the information required was readily available to them and was easy to understand. 'Naive' groups, that had no involvement in the development of ForageMaster®, were used to provide a final test of the interface.

The first stage in using ForageMaster® was to describe the conditions under which the forage would be planted and how the forage was to be used. These settings were used by the software to exclude any unsuitable forages from consideration. For example, in Figure 1, the user has indicated that animals will be set stocked on the forage in spring. This would exclude lucerne and other forages that do not tolerate set stocking.

The second, and final, stage of the data input allowed for the user to describe the features they desired in the forage (Figure 2). These features were used to set the preference or indifference weightings on the forage attributes. The user

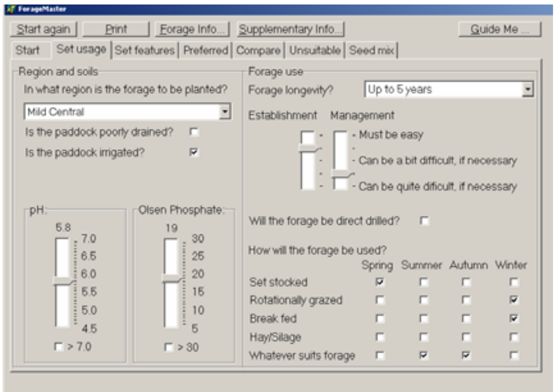

Figure 1. Describing how and where the forage will be used.

could indicate that they desired resistance to various pest and diseases, the importance of yield relative to quality and if they had preferences for yield in particular seasons.

The priorities were ratios within each group. For example, if forage quality was given a priority of "90" and drought tolerance was given a priority of "30", then forage quality would be considered three times as important as drought tolerance in the decision algorithm. As a result, although the scale was marked from "0" to "100", the actual minimum on the scale was "1" to avoid the potential error of dividing by zero. Another consequence was that if the user set all of the priorities to "100", the result would be no different than if the user set all of the priorities to "10".

Those two screens (Figures 1 and 2) provided all the information needed to run the ELECTRE III algorithm and provide recommendations to the user. The preferred forages were presented as a ranked list (Figure 3). Where there was little to distinguish one forage from another, they were indicated as being equal in rank.

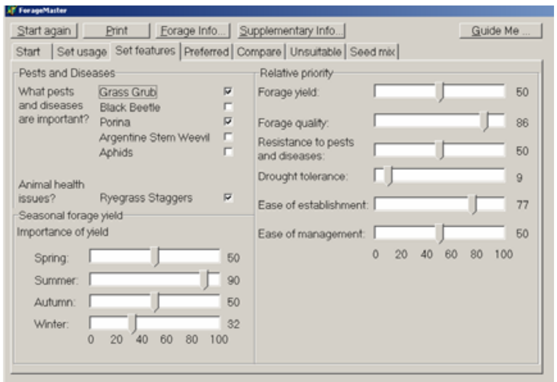

Figure 2. Describing the desired properties of the forage.

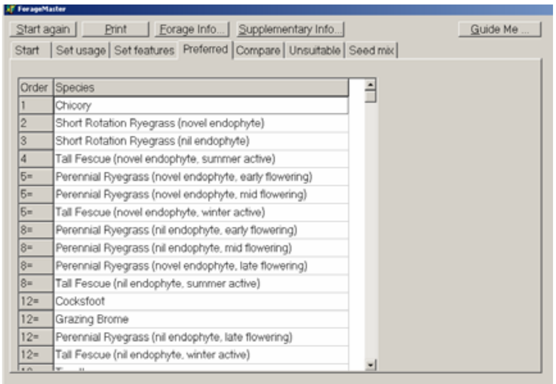

Figure 3. The ranked list of preferred forages.

If presentation of a ranked list of forages was the end-point of the information presented to the user, the information might be useful but it would be difficult for the user to understand the rationale behind the rankings. In Figure 3, for example, the user may well ask why chicory was the top-ranked forage over short-rotation ryegrasses, or why lucerne did not appear on the list given the strong preference for summer yield (Figure 2). Without such information it would be difficult for the user to place much faith in the recommendations or to reflect on the initial requirements of the forage and consider alternatives. If the advice was given by a human expert, the farmer would quickly follow up the recommendation with a series of questions to discover why the recommendation was made. If the expert responded simply "trust me – I know what I am doing", this may paradoxically lead to the farmer distrusting the recommendations unless he/she receives evidence for the reliability of the reasoning behind the recommendations. This problem of distrust was overcome within ForageMaster® by presenting two further sets of information to the user.

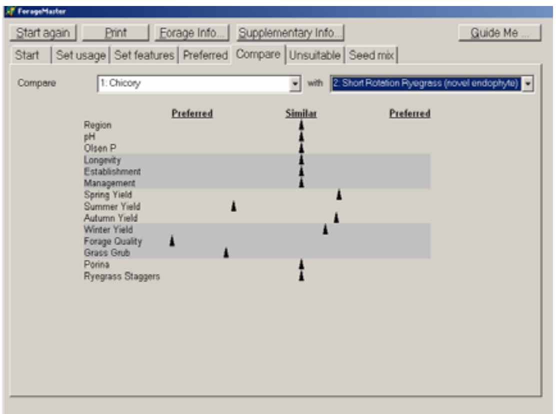

Figure 4. Comparison of forages on the preferred list.

In the first screen of additional information (Figure 4), the user could compare any two species on the preferred list to see in which criteria any forage outperformed another. In Figure 4, it is obvious that chicory had no advantage over the short-rotation ryegrass for several criteria, and that it performed worse in spring, autumn, and winter yield. However the user's high preference for forage quality and summer yield, as well as

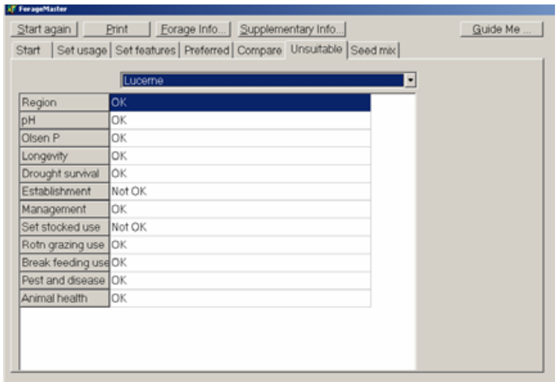

Figure 5. Indication of why some forages were excluded from consideration.

resistance to grass grub (Figure 2) meant that chicory was, overall, the preferred forage.

The second screen of additional information indicated why some forages were excluded from the recommended list. For example, why did lucerne not appear on the list of preferred forages given the user's preference for summer yield and quality? A look at the "Unsuitable" list (Figure 5) quickly showed that lucerne was excluded because it was not easy to establish and it was not suitable for set stocking (see the user's preferences shown in Figure 1). At this point, the user may choose to reassess some of their priorities or preferences. For example, although he/she might need to set-stock during lambing in spring, the farmer might not need to use the lucerne paddocks for this purpose. Alternatively, it may be that the farmer is prepared to put in a little more effort to establish the forage than he/she originally thought. If so, the user can revise some of those preferences or requirements and discover how ForageMaster®'s recommendations would change.

A final screen in ForageMaster® provided seed mix recommendations. After choosing a forage, the interface indicated what, if any, species were known to be suitable companion species. A list of cultivars was displayed for information only as the software assumed that all cultivars were equivalent. Recommended sowing rate ranges were stored in the ForageMaster® database for the chosen species, but the user was free to choose within those ranges (Figure 6). Once the user chose the sowing rates and cultivars for the principal forage and any companion forages, clicking the "Print" button generated a report of the key information that would be required by a merchant to supply the appropriate mix of seed.

At all times while using ForageMaster®, the user could access screens of information about the forage species that included general descriptions as well as establishment and management information. Supplementary information covering animal health issues related to forages and other useful information was also available, and all of this information could be printed out for convenient reference away from the computer.

4. RELEASE AND TRAINING

Software tools released without support are unlikely to be used to any significant degree. To avoid this it was decided that workshops would be held throughout New Zealand to give all sheep and beef farmers an opportunity to attend. As well as providing the DSS to the attendees, these workshops were an excellent opportunity to discuss many aspects of forage selection, establishment, and management with farmers. The workshops were designed using the principles of the AgCelerate® learning programme (see www.agresearch.co.nz/agcelerate). Each of the four-hour workshops included:

- an interactive discussion with farmers about how they go about selecting and establishing forages at present;
- a discussion, with the aid of a cost-benefit calculator, of the importance of forage selection and management;
- an interactive demonstration of the ForageMaster® software with examples provided by the attendees;
- a presentation and discussion of best practice forage establishment and how to maximise performance and persistence of forages.

Farmers left the workshops with a booklet on the principles discussed and a copy of the ForageMaster® software. There was a workshop fee. ForageMaster® was not for individual sale, so farmers had to attend a workshop to obtain the software. This ensured that the appropriate training was supplied with the software and acknowledged that appropriate selection of a forage was only part of the process of pasture improvement and matching supply to demand.

Over 500 farmers attended 22 workshops in early 2005. Thirty additional workshops were scheduled for July and August 2005. A survey of farmers that attended the early 2005 workshops received positive feedback with an indication that farmers perceived they had significantly increased their knowledge, understood more about forage management, appreciated the source of independent advice, and considered the research programme to be a good use of their levy funds.

5. THE DEVELOPMENT TEAM AND THE PROCESS

A range of people, with differing skills and interests, contributed to the development of ForageMaster®. The first phase of development was consultation with farmer groups and this was done by the combination of farm systems scientists and an extension scientist. An additional, more detailed, consultation process was later carried out by one of the systems scientists. Selection and implementation of the decision-making algorithm was done by collaboration between a systems scientist who had expertise in multi-criteria decision making, and a systems modeller/programmer. The interface was coded by another software engineer with prior experience in DSS development while the extensive and iterative process user interface design was carried out by a combination of the software engineer, systems scientists, and farmer groups. The database containing forage species information was compiled by another systems scientist, using a combination of existing reference material and his own expertise. The fifty workshops were run by two farm systems scientists, one at each workshop, over a period of a year.

The team described above comprised seven AgResearch staff with a total commitment of 2.5 person-years spread over a three-year project. Of the 2.5 person-years: 0.5 was expended on consultation; 1.5 on design, programming, and data collation; and 0.5 on the workshops. These figures do not include the time committed by

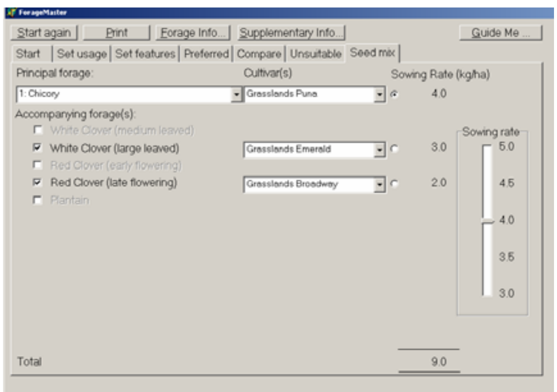

Figure 6. Seed mix recommendations.

M&WNZ personnel, the farmers in the mentor and testing groups, or the forage industry experts. Emphasis placed on the consultation, iterative testing of the interface prototypes, and the extension workshops.

6. CONCLUSIONS

Matching forage supply to demand is a key issue in efficient pastoral production. One of the few tools that sheep and beef farmers have to manipulate supply is the mix of forages on their farm. With an extensive range of species and cultivars available, choosing which forage to sow can be a daunting choice. The ForageMaster® software, and associated workshops, have provided farmers with the information and skills to make and implement appropriate forage selections.

While it is too early yet to state that ForageMaster® has been totally successful in its ultimate aim, to improve on-farm productivity, the degree of farmer interest in attending workshops using ForageMaster® suggests that the software would be well used. The key steps in producing the ForageMaster® software were that:

- it was ensured that the objective of the software aligned well with what farmer mentor groups wanted, and the funding body allowed variation to the originally-planned outputs to accommodate this;
- the software had a very simple, intuitive interface that was refined several times in close consultation with farmer mentor groups;
- the recommendations made by the software were presented in a manner that allowed the user to discover the reasons for its recommendations, and so build trust in the software;
- the software release was accompanied by a large number of workshops, which the farmers had to attend to obtain a copy of the software. These allowed valuable discussion of pasture renovation issues beyond forage selection.

Progress with ForageMaster® will be monitored, but at this stage it seems this has been a successful formula and one that is likely to be followed in development of future tools.

7. ACKNOWLEDGMENTS

ForageMaster® was developed with financial support from Meat & Wool New Zealand. The authors also wish to acknowledge the valuable input of the farmer mentor groups that helped during the design and testing phases of this work.

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