Tropical pasture establishment.
18. The potential for computer-based decision support systems to improve establishment success for sown tropical pastures

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Abstract

Four types of computer-based decision support systems could be developed for pasture establishment in Queensland to overcome the problems of unreliable establishment. These relate to: (1) selection of species suited for the particular usage, location and soil conditions; (2) economic evaluation of the biologically-feasible alternatives; (3) strategic planning of when and how to plant as part of property development planning; and (4) tactical decision support for given planting conditions. The data requirements and the information delivered from each decision support system are outlined.

The main steps in development of computer-based decision support systems are: (1) develop a preliminary model from available data; (2) conduct field experiments to validate the model and fill any information gaps; (3) develop a full simulation model; (4) conduct experiments with the simulation model; and (5) use the output from the simulation experiments to develop decision support systems. *Stylosanthes* spp. are the only pasture species for which there are sufficient data to construct the above decision support systems at this point.

Introduction

Establishing pastures in Queensland's grazing lands can be unreliable. There are a host of interacting factors that can influence the success of any particular attempt at planting a pasture (Gramshaw *et al.* 1993; Stone and McKeon 1993). Because of this complexity, there is no single answer nor are there any simple solutions to the problem of what is the best method of obtaining an established pasture. In such situations, graziers and advisers may benefit from assistance on what should be planted, where, how and when and the associated reliabilities. The general term for this assistance is decision support.

In this paper, computer-based decision support systems are discussed. There are many other forms of decision support systems *e.g.* maps, tables, paper-based decision trees. Where pasture establishment is reliable, these systems are the best forms of decision support. However, in areas with unreliable establishment, computer-based decision support should be considered. The advantages of computer programs are that complex interacting processes can be incorporated into one tool, and many possible alternatives can be explored thoroughly and rapidly, without any direct costs in terms of planting.

However, it must be emphasised that such decision aids are just that, aids. They are not decision **making** tools, and are only one of the sources of information that should be used when making a decision. Local landholder experience, the opinions of seed merchants and extension officers, and printed reference material are all valuable support information that an end-user should consider during the decision making process.

The discipline of computerised decision support is in its infancy and it is probably too early to judge its value. The benefits from decision support development so far have been: (1) in defining current and best practice; and (2) in providing an explicit framework for integration of previously unrelated research. The next stage in the development of decision support systems

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should be to provide the integration of the community's experience in pasture establishment and research/modelling (see papers in this volume). The capturing of this widespread experience in pasture establishment will overcome the major problem facing graziers, advisers and research workers of extrapolating limited personal experience to new situations. We present a plan for the development of computer-based decision support systems in pasture establishment to contribute towards these goals.

Types of decision support systems

One of the dangers in the development of decision support systems is that authors can make them too complex and can attempt to answer too many questions. There is a strong parallel here with some early simulation modelling exercises of grassland systems. Models were built with all possible processes and interactions included. These were not focussed on answering any one particular set of questions, but rather were expected to be able to answer **any** question that was asked of the model. In this respect, they failed, though the construction of these models was extremely valuable because it was the first systems analysis of existing data. Where a variety of questions must be addressed, a series of decision support aids are required. This is particularly so where the types of questions are very different *e.g.* what are the economics of pasture planting? and when should planting be done?

The most important lesson to be learned from experience with simulation modelling was that decision support systems must be targeted at answering specific questions. Determining what those questions are is an important, but sometimes neglected, step in the process of developing decision support systems. Technologists can easily devise systems that will answer particular questions which end-users are **not** asking. However, end-users may not appreciate the potential power and flexibility of computerised decision support systems. Thus, end-users should be involved from the beginning of a project to build a decision support system and the system should be designed to capture the experience of users.

In sown pasture establishment, 4 categories of decision support systems could be constructed: (1) species selection; (2) economic evaluation; (3) strategic planning; and (4) tactical decision support. These are targeted at answering specific aspects of pasture establishment. While it is conceivable that the 4 could be combined into one system, that approach could make the resulting system unnecessarily complex without adding to overall utility.

Species selection

This system would address the question: 'What species will establish and grow at a particular location?'

Inputs. The requirements are:

(1) What is the purpose of pasture? Pastures have a range of uses *e.g.* grazing of beef cattle, dairy cattle, sheep and horses as well as waterway stabilisation and erosion control. Different end-uses will limit the choices of pastures that are appropriate.

(2) Where is the pasture to be planted? Location within the state can influence abiotic factors important to the establishment of a pasture *e.g.* frost frequency and severity; length of growing season; year-to-year rainfall variability; summer versus winter rainfall distribution.

(3) What is the level of soil fertility? This is important for plant growth rather than establishment *per se* (Jones 1990). Two cases are worth noting here. *Cenchrus ciliaris* requires higher soil phosphorus than native grasses to produce tillers. Low soil phosphorus increases the time taken to tillering, thereby increasing the likelihood that moisture stress will occur before the plant is well established (Christie 1975; Silcock and Smith 1982). The second case concerns *Stylosanthes scabra*. This species will establish and grow on soils with low phosphorus (Jones 1990). However, animal production is quite low at these levels and additional phosphorus must be added in the form of fertiliser for the plants or as a supplement for cattle (Kerridge *et al.* 1990).

(4) What is the water-holding capacity of the soil? This is an important factor as it influences growth as well as the reliability of establishment, and can interact with soil fertility.

Output. The main output of this decision support system would be what species, seeding rate and seedbed preparation method would be appropriate for the pasture use, and what is the probability of successful establishment and pasture longevity. There are about 70 possible pasture species in Queensland (Rains *et al.* 1993). For each of these, it would be possible to produce maps or tables containing this information, although there are insufficient data available for most commercial cultivars.

This is the most general level of interest. It is a scanning exercise which sets limits to the possible suite of species. These data are important for the next stage which is economic assessment of the alternative pastures available.

Economic analyses

From the previous analyses, a number of alternative species may be biologically capable of being successfully established at a location. Would it be profitable to establish and maintain these pastures? If there were alternatives, which would be the best?

Economic analyses must incorporate many factors. Some of these are easy to describe (*e.g.* cost of planting, interest rate) but some are attitudinal characteristics of the landholder (*e.g.* what is an acceptable risk of failure?). Many economic parameters are dynamic, fluctuating rapidly and over wide ranges. The large number of inputs that may need to be considered and the dynamic nature of the economic measures preclude the use of tabular information or simple rules for aiding decision making.

Landholders and economists often assess economic profitability differently. There is a **development** ethic among many primary producers, especially in areas where pasture establishment is unreliable *i.e.* on the margins of adaptability of pasture species. In these cases, a pasture planting program may be embarked upon, even though formal economic analyses may indicate that it is not the best use for that money. However, even in these cases, producers need to know the financial implications of their choices of development.

Any economic assessment package must be very flexible and allow for individuality. It must force the user to address all aspects of the issue and allow for a variety of assumptions to be put into the model.

Many assumptions or defaults are necessary in any modelling exercise and in this case, the user must explicitly accept or reject any assumption or default that is used. There have been too many cases where an **academic** economic analysis has been rejected because the end-users have not accepted the basic assumptions in the model.

Inputs. The requirements are:

(1) Direct costs *e.g.* seed, fertiliser, seedbed preparation.
(2) Associated costs *e.g.* fencing, extra stock, finance. The costs used in an evaluation exercise may depend on the purpose of the analysis *e.g.* for discounted cash flow or for end-of-year tax treatment. For some purposes, the cost is only that money directly outlaid during the pasture establishment program, while for other purposes, cost will include maintenance, depreciation on equipment, taxation considerations and the opportunity cost of money tied up in all phases of the pasture establishment program. These differences will often result in different conclusions being reached after analysis.
(3) Maintenance costs *e.g.* fertiliser, renovation, weed control.
(4) Altered productivity of paddock or property *e.g.* for beef cattle production, what is the new stocking rate and the new liveweight gain per head?
(5) Time profile of development. This includes how much land will be treated each year as well as the time taken for the pasture to reach maximum productivity and the longevity of the pasture once established. This time profile is very important as most economic analyses use some form of discounted cash flow for their assessment. The important feature of these analyses is that income or expenditure occurring early in the program will have a greater impact on profitability than similar income or expenditure later in the development cycle.
(6) Sensitivity to maintenance inputs. An example of why this is important concerns tropical grass-legume pastures, some of which require high fertiliser inputs to maintain productivity. During the beef slump of the mid-1970s, fertiliser applications almost ceased and many pastures reverted to grass-only pastures (Anderson *et al.* 1983), with a marked reduction in animal production.

The sensitivity of any pasture system to such altered inputs must be considered as part of risk assessment.

Output. Two areas must be addressed:

(1) The economic performance of all alternatives (one of which must be the 'do nothing' option) should be evaluated. A projected cash flow of gross margin per animal and per hectare, as well as payback period, net present value and internal rate of return should all be provided, even though these provide essentially the same information. The users should select which option to use, in conjunction with their economic advisers.
(2) The impacts of higher costs, reduced product price, reduced pasture productivity (disease, lack of fertiliser, drought, overgrazing) should be assessed wherever possible. Different attitudes to risk will influence the choice of options *e.g.* some landholders will seek maximum profit over an extended period, but with the possibility of large scale fluctuations; others will choose a lower overall profit if accompanied by small annual variation in income caused by fluctuations in costs, returns and weather. Individuals should make the choice, based on their particular economic needs and personal attitudes.

Strategic planning

This decision support system would assist in choosing the most appropriate planting date, planting method and fertiliser requirements for the pasture species capable of growing in the region and able to meet the economic goals of the landholder. The system would be heavily reliant upon an establishment simulation model.

Inputs. For the simulation model, the following data are required:

(1) Daily weather data e.g. rainfall, vapour pressure deficit, evaporation, maximum and minimum temperatures, for as many climatic stations as possible.
(2) Soil surface characteristics e.g. litter, crusting.
(3) Soil water-holding capacity by layer.
(4) Soil fertility.
(5) Species requirements for all stages in establishment.
(6) Planting method.

Output. Long-term simulations would:

(1) Allow the establishment percentage (% of seeds that establish) and the probability of successfully establishing a permanent pasture to be estimated for each species by soil type by planting method by weed level by location.
(2) Enable the required planting rates to achieve the target population in a certain time period to be determined.
(3) Indicate the year-to-year variability encountered, and allow this to be related to seasonal conditions *e.g.* El Nino-Southern Oscillation events.
(4) Allow the best long-term planting date to be estimated.
(5) Enable an evaluation of the usefulness of weather predictions (Southern Oscillation Index, 30–50-day wave; Stone and McKeon 1993).
(6) Indicate the time required to full pasture development and the longevity of that pasture.

These results could be stored as maps indicating the level of each of these parameters for each location in an area of interest (*e.g.* the state of Queensland, or the *Astrebla* grasslands). While these could be stored in a paper-based system, the sheer volume of information may make it more practical to store the output as layers in a geographical information system or as response surface models. However, the simplest form of storage of information that is consistent with the needs of the end-user should be used.

This information would be used to refine the economic assessments. However, at this stage, there are no models sufficiently well tested to use as the generator for a decision support system along these lines.

Tactical decision-making support

This decision support system would help answer the question of whether seed should be planted, given current and expected conditions. Of all the decision support systems discussed, this one would have the greatest data requirements and therefore would be the most complex to use.

Inputs. The requirements are:

(1) Detailed site description, especially soil surface characteristics.
(2) Soil moisture profile at the time of planting.
(3) Seed characteristics (germination percentage and hardseededness).
(4) Planting method and depth.
(5) Future rainfall scenarios. These could be derived from several sources including: a stochastic weather model; historical rainfall patterns; predictive model which incorporates the Southern Oscillation Index, 30–50-day wave and any other feature which could have some predictive power.

Output. Information produced would be:

(1) Probability of a given establishment percentage.
(2) Probability of successful establishment of a pasture.

The user would decide: what was an acceptable level of establishment; what seeding rate should be used; and on that basis, whether or not to plant.

Stages in development of decision support systems for pasture establishment

We propose 6 stages in the development of the strategic planning decision support systems:

(1) Research the characteristics of pasture establishment for the species and conditions of interest. Some information will be general (*e.g.* rate of soil drying, lethal temperature for a germinated seed), while other data will be species specific (*e.g.* percentage hardseededness, rate of radicle elongation). There are sufficient data for *Stylosanthes* spp. to construct a preliminary model (Stone and McKeon 1993).
(2) Develop a preliminary simulation model. Two phases must be modelled. The first deals with the germination and initial establishment of **individual plants** and has a time frame of weeks to months. The second phase is the establishment and growth of **a pasture** *i.e.* plant regeneration, competition between planted pasture and other species and the changes of populations over time in relation to weather and management are simulated. This second phase is poorly understood for most species, although a model could be constructed for *Stylosanthes* spp. based on information in this issue.
(3) Conduct field experiments to test the validity of simulated results from the preliminary model and to quantify those relationships within the model that were not based on experimental results.
(4) Develop a full simulation model and test against independent validation data.
(5) Conduct simulation experiments with the validated model to explore behaviour of the modelled system under extreme conditions as well as under normal conditions.
(6) Use the output from simulation experiments to develop a decision support system.

Stages 3–6 above have not been completed for any pasture species in Queensland. Given that about 40 commercial cultivars are traded in Queensland (Rains *et al.* 1993), strategic planning and tactical decision aid decision support systems will be developed for only the most important species.

Myths about decision support systems

There are some similarities between attitudes toward decision support systems in the 1990s and those toward simulation modelling in the 1960s. Some proponents have been over-zealous in selling the benefits of computer-based decision support systems, and this has resulted in some unrealistic expectations of what decision support systems can deliver. These unrealistic expectations include:

(1) Simple systems (including computer models) can replicate all the complexities of the real-life system being modelled.
(2) Everyone or every situation needs a computer-based decision support system. One of the key points to be addressed here is the process by which a decision to develop a decision support system is made. Experience with GRASSMAN (Scanlan and McKeon 1990; Clewett *et al.* 1991) has shown the importance of involving end-users from conception through development and construction to promotion.

(3) Decision support systems can **make decisions** for you. Decision support systems are only one source of information and should be used in conjunction with all other available information. Decision support systems should not be seen as replacements for extension officers or reference libraries, and their output must be examined critically before a decision is made.

(4) Decision support systems are easy to build. Simple systems cannot mimic the real world situation precisely, and complex models are difficult to construct and validate. Not all sources of variation can be included in models.

(5) Reliable information can be obtained from a decision support system even though incomplete data are entered. It is unrealistic to expect that a decision making process, too complex to complete in a person's head, can be completed **sensibly** by a computer model with little input of conditions from the user.

Conclusion

Computer-based decision support systems for sown pasture establishment are feasible. A thorough analysis is needed of situations in which pasture establishment problems could be alleviated (at least partially) by access to computer-based decision support systems. End-users should be involved in the process from the initial assessment of need to the development of any systems to be built.

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