Using technology to improve the sustainability of grazing systems in high rainfall landscapes

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Abstract

Computer-based decision support tools offer a powerful new way of putting science to work on farms. The \textbf{GRAZPLAN} family of tools assists graziers to identify the “profit drivers” in their businesses, to control business risks and to meet market specifications for product quality and supply. In some cases, the new tools can assist farmers to break from conservative practices that can lock their enterprises into a downward spiral in profitability. Conservative management is mainly a consequence of Australia’s extremely variable climate and is a hedge against drought. However, the cost of this is low profitability and lost opportunities in good years. The computer tools provide a very different way of dealing with climatic variability by quantifying the business risks and determining the probability that an outcome may be achieved. This can assist optimistic management practices and better marketing strategies. The tools are also used to assess the impacts of farming on the environment and in the future, will be combined with novel information sources such as geographic information systems and remote sensing to open further opportunities for effective decision making in the farm sector.

Introduction

For half a decade many grazing enterprises in higher rainfall areas have returned marginal or negative profits. (Holmes, Sackett & Assoc. 1999a; Beattie 1999). The poor returns coincide with a need to address significant environmental issues such as soil acidification, rising water tables and salinity. Grazing enterprises that are unprofitable are neither sustainable nor able to address environmental issues.

It is not always apparent what generates profit in a grazing enterprise, or how to change management to produce high value commodities at reasonable cost. Some graziers respond to declining profits by reducing inputs such as fertilizer and thus commit their enterprises to ever diminishing production and profitability (Lean et al. 1997). In complete contrast, others implement changes to management that directly increase profits. In particular, they improve the quality and value of their products and enhance production per hectare. In many cases the key to higher profits is change that supports higher stocking rates. This reduces the cost of each kilogram of product and profitability is maintained or improved, even when commodity prices are low (eg. Webb Ware, 2000; Daniels, 2000).

Decision making on farms

Why is it that the operators of essentially similar farm businesses have adopted such widely divergent paths? Part of the problem is the difficulty of managing the complex physical and biological environment of a farm in Australia’s highly variable climate. When combined with unpredictable commodity prices the result is a very volatile and risky business environment. Confidence to increase investment in a farm and to opt for
an “optimistic” business path will depend, in part, on the ability to quantify the consequences and risk of management options.

What are the “certainties” in such an uncertain environment?

Continued profitability depends on achieving a low cost of production
The key to achieving a low cost of production is to lift productivity without increasing the overhead costs of the enterprise. If we take wool as an example, there is a very large variation in the costs of production between farms (eg. 500 c/kg clean (top 20 per cent) to 836 c/kg clean, (bottom 20 per cent) (Holmes, Sackett & Assoc. 1999b). Clearly there is scope to lift profitability. Cost-effective steps to increase production in a grazing enterprise include changes to lambing or calving date to better match feed supply to livestock requirements and to use fertilizer to boost pasture production. These strategies create the opportunity to increase stocking rates and generate extra income. Improving the breed or bloodline can increase the productivity and value of the animal enterprise. Attention to animal health and flock or herd structures can reduce costs and protect the investment.

Knowledge and good advice are valuable commodities
The complexity of farm businesses is a barrier to effective decision-making that is not widely acknowledged. The common grazier complaint that “there is too much information” is a reflection of the difficulty of the job. The competent grazier ideally needs expertise in a range of disciplines and an understanding of how they interact with other aspects of the farm business cycle. Producers must stay abreast of new technology. Marketing and business skills are also essential for survival in a constantly changing economic environment. To acquire so much expertise would be difficult for even the most competent grazier; the solution for many is to use consultants to help fill the knowledge gaps.

Drought
Periodic drought is a certainty in most areas of Australia. Memories of its devastating impact can bias the analysis of business risk. One consequence is that many farms in the bettered watered areas of southern Australia are conservatively stocked (Rossiter and Ozanne 1970; French 1987; Obst 1987). Effectively, this is a way of hedging against the uncertainty that results from a highly variable climate, but there is a high cost. Profitability is low, cash flow is restricted, the benefits of new technology (eg. new pasture cultivars) cannot be fully realized and it is more difficult to exploit the production opportunities that occur in good seasons. Over the longer term, a conservatively stocked farm is less likely to have the financial resources to cope with the most extreme droughts.

Decision making on farms is complex
Australia’s highly variable rainfall makes farm decision making particularly difficult. High stocking rates are the primary profit driver in grazing enterprises. However, it is a major decision to move from a low input, low production enterprise to a high input, high production enterprise. In the first instance, the normal year-to-year variations in climate and consequently production, make it difficult to determine the target stocking rate for the enterprise. As discussed previously, experience of droughts in particular, is a powerful disincentive. It is also likely that the shift to a higher production system will expose the business to different and perhaps larger financial, climatic and business risks.
New skills for managing the biology of the grazing system may be required, with better monitoring skills, improved financial management and a drought plan.

Harnessing computer technology to assist sound decision making

Computer-based decision support tools (DS tools) are designed to help graziers focus on features of their business that lift profitability and to estimate the biological and financial risks. Some tools access large databases for information while others use mathematical models to simulate the whole, or part of a grazing enterprise. CSIRO has developed the GRAZPLAN series of DS tools (Donnelly et al. 1997) to assist decisions about the feeding of livestock and the management of grazing enterprises.

How do DS tools work?

Figure 1 illustrates the main component models of the GrassGro DS tool which simulates sheep and cattle enterprises based on grazing pastures in southern Australia (Freer et al. 1997; Moore et al. 1997). The components simulate the major processes that occur in grazing systems: animal nutrition and production, plant development and growth. The processes are responsive to the soil, weather and grazing regime that is specified by the user. The mathematical complexity of the models is hidden and the GrassGro user can concentrate on the consequences of altering grazing management or of using, for example, a particular plant species or livestock breed.

The DS tools are used increasingly to assess the sustainability of current practices for the environment. Because environmental damage can be slow and insidious, these tools give us a way to identify practices that may have adverse environmental consequence.

Figure 1. Main components of the GrassGro decision support tool. Daily historical weather records are used to “grow” pasture with constraints imposed by the soil and the management preferences specified by the user. Sheep or cattle graze the pasture. The breed/bloodline is specified by the user. The value of animal products and the costs incurred in their production are tallied to predict annual gross margins for the enterprise. Risk due to year-to-year variance in production or gross margins can be quantified.
What can a computer tool do that is different?
Tools like GrassGro complement existing methods of extending new information, but they also have a number of unique advantages:

- they can simulate the grazier’s own farm, climate, enterprise and management preferences. This enables graziers to explore the potential of a new technology and removes doubts about its applicability. The potential productivity of a farm can be simulated to assist realistic district and local area benchmarking;
- the latest technology and knowledge is available to the grazier whenever the underlying models are updated;
- the physical and financial consequences of a management change can be assessed before dollars are committed. This helps to keep the focus on the real “profit-drivers” of the enterprise;
- management changes are analysed in the context of the whole enterprise and unforeseen production and environmental consequences of an action can sometimes be identified;
- business risks, particularly those due to climate variability, can be quantified. This assists adoption of optimistic management;
- the tools can be used for strategic planning to position the management of an enterprise for the long run, and for shorter-term tactical planning to capture production opportunities.

An important caution. Computer-based DS tools offer a unique and comprehensive framework in which to test options, but they are only intended to support decisions; decision making is still the job of the farmer. The predictions generated by a computer model are only as good as the knowledge coded into the process models. “Errors” occur when knowledge is incomplete and when the input information required for the simulation is inadequate.

Achievable production targets: strategic planning with GrassGro.

The problem
For a number of years, incomes achieved on many farms in districts near Yass have been inadequate to sustain viable rural businesses (Boyce & Co. 1999). Low stocking rates and low use of superphosphate contribute to the poor profitability. Experience had shown that although unfertilized pastures with native species grew less feed (Fig. 2), the wool was sound and very fine, and sold for a good price per kilogram. The problem was that wool cut per hectare was too low to sustain a viable business.

Farmer members of the Bookham Agriculture Bureau were not prepared to accept that wool production was unprofitable. They established a grazing demonstration to see if superphosphate could be applied to native grass-based pasture to lift stocking rates and
profitability. It was critical to prove that fibre diameter could be controlled by grazing pressure as a “blow out” in micron† could destroy the potential profitability.

![Graph](image-url)

Figure 2. Estimated monthly average growth rates for fertilized (plain) and unfertilized pasture (hatched) growing at Bookham, NSW (unpublished data; P. Graham).

The demonstration indicated that graziers can take better control of the viability of their businesses by increasing stocking rate (Table 1). Wool cut per hectare was doubled, wool micron was controlled and profitability was doubled.

Table 1. Average annual production from grazing Merino wethers at Bookham for the period Nov. 1993 - Nov. 1998 (from Graham and Hazell, 1999).

<table>
<thead>
<tr>
<th>Stocking rate (wethers/ha)</th>
<th>Clean wool (kg/ha)</th>
<th>Clean wool (kg/hd)</th>
<th>Fibre diameter (micron)</th>
<th>Staple strength (N/Kte x)</th>
<th>*Profit ($/ha)</th>
<th>Cost of production ($/kg clean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No superphosphate</td>
<td>6.3</td>
<td>20.7</td>
<td>3.29</td>
<td>19.5</td>
<td>35</td>
<td>35.09</td>
</tr>
<tr>
<td>Superphosphate</td>
<td>11.8</td>
<td>39.9</td>
<td>3.38</td>
<td>19.7</td>
<td>34</td>
<td>72.25</td>
</tr>
</tbody>
</table>

† The thickness of the wool fibre (measured in microns) increases (“blows out”) when sheep are fed more or better quality pasture. Micron determines the price received for wool and thicker wool fibres can be worth considerably less.
*Profit is calculated as net farm income using the wool price current after Nov. shearing (approximate average fleece price, unfertilised pasture = 914 c/kg clean; fertilised pasture = 870 c/kg), variable costs of production, and an allowance of $90/ha (based on local data) for the fixed costs of production.

An achievable stocking rate target

Over the 5 years that the demonstration was running, the Bookham group arrived at a stocking rate for fertilised pasture of about 12 wethers/ha. Rainfall at the site averaged about 710 mm/year and the French-Schultz calculation (French, 1987) predicted a potential stocking rate of 24 wethers/ha. How could the Bookham demonstration be so wrong? What was holding this site back? The soil is very acidic, can be waterlogged in the winter, and the pasture is native grass with annual species (including sub clover); were these the problem?

**GrassGro** was used to provide an alternative estimate of the potential stocking rate for the Bookham site (Simpson et al. 1999). In contrast to the French-Schultz calculation which is based solely on average rainfall, **GrassGro** computer simulations take account of key features of the production system including properties of the soil profile, the pasture species growing at the site, local weather records, the sheep bloodline and the management regime.

**GrassGro** predicted that the likely longer-term potential stocking rate at Bookham was about 12 wethers/ha (Fig. 3); very similar to the outcome of the demonstration. The predicted gross margin increased as stocking rate increased from 6 wethers/ha. This was initially associated with proportionate increases in the year-to-year variability of the gross margins (region “A”). Although stocking rates above 14 wethers/ha had the highest average gross margins, the variability of the gross margins at these stocking rates was disproportionately large (region “B”) indicating increased business risk at the higher stocking rates. A stocking rate target of about 12 wethers/ha avoided disproportionate increases in business risk. The increased risk was mostly due to escalation of the need for supplementary feeding in poorer years at higher stocking rates (Fig. 4).

**Land capability**

The French-Schultz prediction of 24 wether/ha was apparently not an achievable, long-term target for the Bookham site. Why?

The **GrassGro** simulations were examined to answer this question. Land capability or production potential of any site is influenced mostly by the amount and reliability of
rainfall, the pasture species present, and soil constraints such as acidity, fertility and water holding capacity. The overriding influence at Bookham proved to be soil constraints. Firstly, the capacity of the soil to hold water that plants could use was only about 7 per cent by volume. This is very low (many soils have up to three times this capacity). Secondly, the subsoil was very dense and would restrict root growth. GrassGro predicted that only about 30 mm rainfall could be stored in the root zone at this site. This is only half of the 60 mm rainfall that is received on average every month at Bookham!

The importance of soil type in determining land capability was further illustrated when GrassGro was used to explain the difference in carrying capacity achieved at Bookham and at a site on CSIRO’s Ginninderra Experiment Station near Hall which receives a similar annual rainfall but was known to be capable of carrying at least 20 wethers/ha. The simulations were identical to those undertaken for the Bookham site, except that soil characteristics for Hall were used. They indicated a carrying capacity of 20 wethers/ha was appropriate. The higher stocking rate was possible because the soil profile could hold about 80 mm rainfall in the root zone (Fig. 5).
farm near Hall and a farm near Bookham. The analysis assumed near-optimum soil fertility. Potential carrying capacity may be that which yields a high gross margin with acceptable business risk (e.g. between 18-22 wethers/ha at Hall and 10-12 wethers/ha at Bookham).

This example shows how a computer-based tool can be used to help set achievable production targets that are compatible with the climatic, soil, pasture and livestock resources of a farm. The analysis also takes account of business risk due to climate variability and can help to encourage an optimistic management outlook because the risk is quantified.

**Capturing market opportunities; an example of tactical management**

Opportunistic purchase of animals in favourable seasons can significantly boost farm income but is also likely to involve significant business risks. For example, prevailing pastoral conditions may be ideal to support additional animals purchased for fattening for a specific market. However, if normal seasonal rains fail it may become impossible to sustain animal growth at a rate sufficient to reach the target market weight. This can also place the main farm enterprises under increased pressure, threatening normal farm income. **GrassGro** can be used before a decision is taken, to assess the risks associated with seasonal production or marketing opportunities.

To illustrate this, consider the purchase by a farmer in the Holbrook area of NSW, of weaner steers to fatten for the domestic retail trade or for sale to a feedlot for further fattening on grain.

The producer is making the decision in early February and sets up **GrassGro** to mimic the prevailing pasture conditions in the paddocks that will be used and describes the animals that are likely to be purchased in the following week. The tactical run simulates from the current pasture condition, forward in time by using the historical weather record. Of interest to the producer is the likely steer liveweights that can be achieved by the expected sale date (30 Nov.). Figure 6. shows the probability of achieving differing liveweight outcomes given three alternative stocking rates.

There is a 95 per cent chance of reaching the minimum live weight for the domestic retail trade (330kg) if the producer grazes the animals at 2 steers/ha. This reduces to 85 per cent and 73 per cent respectively at 3 and 4 steers/ha. To capture a possible marketing opportunity and sell into an export feedlot the steers must reach 400kg. This could be achieved one year in two given similar seasonal starting conditions if grazing at 2 steers/ha, but there would only be a 1 in 5 chance at 4 steers/ha.

This form of business risk assessment gives a measure of the variability that is due to the impact of day-to-day weather on feed supply and would normally be combined with further economic analysis when making a business decision.
Figure 6. Probability of achieving any desired steer liveweight by 30 November at stocking rates of 4 steers/ha (thin line); 3 steers/ha (dashed line) or 2 steers/ha (thick line). Minimum target liveweights for domestic trade (330 kg) or export feedlot entry (400 kg) are indicated.

Tactical simulations are not just about capturing new markets and production opportunities. They can also be very helpful when preparing a business for expected adverse conditions. For instance, Alcock et al. (1998) report tactical preparations for an anticipated feed shortage due to drought.

Addressing environmental issues

Ideally farm practices should reflect current, knowledge of how to produce food, fibre and profits in a sustainable way. However, history shows that we are not always blessed with complete knowledge or impeccable foresight. Land management practices have sometimes failed to be sustainable. Examples from our past include nutrient depletion of soils under cropping systems prior to about 1900, and losses of soil through water and wind erosion. The nutrient balance of depleted soils was addressed by shifting away from continuous cropping to better crop rotations, legume-based pastures and fertilizer use (Hamblin and Kyneur 1993). Although wider adoption of minimum tillage and other soil management strategies is still needed, there is evidence that soil erosion has been greatly reduced by these better farming practices (eg. Hairsine et al. 1993; McTainsh and Reddan in SEAC 1996).

Today soil acidification, rising water tables and salinity have emerged as major on- and off-farm threats. The farm sector will respond positively to these challenges, so we should be optimistic that further solutions will be implemented on farms. However, there is certain to be pain and need for rural re-adjustments. How can the new tools be used to assist in implementing solutions?

Figure 7. shows predictions of the “leakiness” of typical annual and perennial pasture systems at Hamilton, Victoria, using GrassGro linked to SWIM (Verburg et al. 1996). Pasture systems are not as “leaky” in some districts as in others and the predictions have been useful in showing why this is the case (Simpson et al. 1998). They also demonstrate that good management practices can help to reduce drainage losses, but are
not always sufficient to stop excessive drainage. The predictions support the call for wider use of perennial species in pastures and indicate that they will reduce deep drainage.

![Figure 7. Estimates of the drainage likely to occur below the root zone of an annual grass-sub.clover pasture (1); a phalaris-sub.clover pasture (s) and a mature eucalypt woodlot (n) growing near Hamilton, Victoria. Pasture systems were simulated using GrassGro, the water budget and woodlot were simulated using APSIM (Simpson et al. 1998).](image)

However, they also demonstrate that very deep-rooted vegetation (e.g. lucerne or trees) is also desirable.

The debate about the water use and “leakiness” of pasture systems is supported by increasing numbers of field experiments intended to suggest, or test land-use solutions. Issues of how much, and where to place deep-rooted vegetation, and about possible land retirement are now part of the discussion (Lefroy and Stirzaker 1999; Ridley et al. 2000). This raises questions that farming systems models can help to answer:

- how much land is needed for a grazing farm to remain profitable?
- can the same amount of food or fibre be produced on less land and how (e.g. Fig. 3)?
- which parts of the landscape are most productive (e.g. Fig. 5)?

**Progress in the development and use of computer-based tools in Australia**

There has been considerable scientific effort in Australia to model various biological, physical and economic aspects of farming systems and landscapes (Hook 1997). Most computer models have been developed for use in scientific research. They are particularly valuable for understanding complex systems where experiments would be very large, technically difficult and costly. The GRAZPLAN series of decision support tools are unique in that CSIRO has taken the farming systems models that were developed for research, and repackaged them for decision support in grazing enterprises. This has placed Australia at the leading edge of the development of decision support tools for graziers, although at present they are mainly used in association with advisers.

It is worthwhile to reflect on the progress of adoption and the identifiable benefits that have occurred since the release in 1989, of the first GRAZPLAN decision support tool, GrazFeed. GrazFeed is used to assist decisions about livestock feeding (Freer et al. 1997). Initially, GrazFeed was used mainly by livestock extension officers in NSW Agriculture. There was a period of about four years during which the early adopters...
gained confidence about the reliability of predictions from a computer tool. Also, many users had to develop new pasture estimation skills in order to use GrazFeed. Livestock officers found the tool useful because it assisted them to make consistent animal feeding decisions. Subsequently, NSW Agriculture developed the PROGRAZE extension program for graziers which teaches them, amongst other things, the pasture estimation skills needed to use GrazFeed.

The partnership of GrazFeed and PROGRAZE has established new benchmarks for grazing management and changed the skill base of a large part of the grazing industry. PROGRAZE is one of NSW Agriculture’s most successful extension programs (Bell and Allan, 2000) and courses are now offered across the southern states of Australia. Many graziers and advisors own and use GrazFeed. However, the influence of the tool is much wider than those who directly use it. Many more graziers benefit indirectly from new industry benchmarks and from more consistent and objective advice. In 1992, it was estimated that recurrent direct savings to sheep graziers in NSW alone was $7.5M/year as a result of better targeted supplementary feeding (G.C. File, NSW Agriculture, pers. comm.)

GrazFeed was the pathfinder in this area. It is a tactical tool to manage livestock nutrition on a day-to-day basis. The GRAZPLAN toolkit has now been expanded with the addition of GrassGro to allow strategic planning of grazing enterprises as well as tactical management of flocks and herds.

What will the future look like?

This is still a new technology in agriculture. It is only in recent years that personal computers have become powerful enough to run the models efficiently. However, computing technology is moving so rapidly that we envisage that small hand-held computers will soon be capable of running decision support tools.

Good decision support software will always be under review and development to incorporate new scientific knowledge. Each new version will be more reliable, flexible and easy to use. As the software is developed and its use becomes more commonplace, we will see increasing use of the tools by graziers.

In time, decision support tools will be linked to other new technologies such as remote sensing. Proof of concept research has linked GrassGro analyses to satellite images that reveal aspects of land capability (Hill et al. 1999; Hill et al. 2000). The imagery shows the areas of relative productivity across individual paddocks or the whole farm;

‡ PROGRAZE was initially developed by NSW Agriculture but has been taken Australia-wide by Meat and Livestock Australia in cooperation with state Departments of Agriculture.
Figure 8. Use of remotely sensed data and the GrassGro DS tool to map the productivity of a farm: a) pasture growth status classes were derived from satellite imagery for “Chiswick” on the Northern Tablelands of NSW and were used to set the soil fertility scalar in GrassGro; b) botanical classification of the paddocks was used to define the pasture types to be simulated in each paddock; c) pasture production was simulated using GrassGro and average annual production was mapped to a map template based on a) and b) (Hill et al. 1999).

the computer model adds value to this by enabling the impacts of changed management to be quantified. Figure 8. shows a farm plan, related satellite image and the derived GrassGro predictions of pasture productivity for a property at Armidale, NSW. Differences in the productive capacity of paddocks are clearly seen, as are differences within paddocks. These analyses have the potential to point out areas of the farm that need additional attention (eg. more or less fertilizer, or altered fencing) to improve pasture utilization. Where tree planting or land retirement is required for landcare reasons, the productivity maps may have a significant role in identifying what parts of the farm can be retired with least impact on farm income.

Conclusions

Decision support tools may enhance the financial sustainability of grazing enterprises by assisting individual farmers to manage the risks and opportunities presented by climatic variability. However producers will be increasingly required to quantify and justify the off-farm impact of their land management practices on the environment. Smarter farming in the future will require processes and technologies that enable farmers, financiers, land managers, policy makers and the public to understand and integrate the complexity of agriculture and land use in Australia. Decision support tools have a major role in this process.

References


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