Managing and developing plants for variable climates

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Abstract
Managing livestock in variable climates requires as much a focus on the plants as on animals, and decisions must be made before there is a visual deterioration in livestock condition. A flexible approach to management is needed. The basic relationships between herbage mass and animal performance can be used to estimate when it is time for animals to be moved. Selling animals early often means a better price than when droughts are obvious. As dry seasons develop within a region, the conditions that apply for pasture growth become more typical of naturally drier regions, e.g. the tablelands in NSW may become more like the slopes. In general, for plant survival, the lower the rainfall, the lower the level of forage utilisation that should apply. Thus, as dry seasons develop, even greater reductions in stocking rates may be needed to maintain pasture species, otherwise the costs of resowing need to be considered. Both native and exotic plant species can survive droughts if appropriately managed. Fencing on a landscape basis and excluding more sensitive areas as dry seasons develop are important. Setting minimal levels of herbage mass, below which grazing should not go, builds in a trigger point for decisions and also enables reduced utilisation as dry seasons develop. However, further work is needed to better resolve the minimal herbage mass values needed in different seasons to maintain livestock and pastures. Plant breeding is often seen as a 'magic bullet' but it is unrealistic to expect any plant to grow without water. Selections for better recovery from grazing and stressful conditions are important criteria, though this can also be achieved to some extent with good management. Wetter years may not immediately improve incomes when it is not possible to obtain extra livestock, but they are good opportunities to cost-effectively rehabilitate degraded pastures.

Key words
Grazing management, utilisation, pasture states, herbage mass, plant breeding.

Introduction

Recent years in Australia have highlighted the highly variable nature of the climate within which agriculture functions. Even those living in metropolitan areas have started to appreciate the importance of climate, and that to live in Australia requires the development of tactics and strategies which work with the climate, rather than seeking to impose a completely artificial system upon the landscape.

It is an opportune time to review how grassland systems in Australia are managed and what our choices are as we continue to seek more efficient production, faced with ever declining terms-of-trade for livestock and grassland products. This discussion paper aims to provide an overview of some of the key factors we can consider as we seek more efficient livestock production systems on grasslands.

Managing animals vs plants

Managing within variable climates requires, by definition, an ability to vary management – to be flexible. Livestock management used to primarily focus on the condition of the animals, and when they were visually losing weight, decisions would then be made to reduce numbers or remove stock from paddocks. In practice, weight loss of livestock can only be detected visually after the animals have lost considerable body mass. By that stage, the pasture may already be seriously degraded.

This decision-making process assumed that the plants providing forage were bullet proof, they could grow without rain, and all would recover after a drought. Examples can be found of good recovery, but often it was not. Perennial grass swards were typically replaced by annual species and the grassy ecosystems became unstable (Moore 1970). By waiting until animals visually lost condition, the pasture had probably been overgrazed to the point where recovery was severely hampered and erosion risks were considerable.

Over the last twenty years there has been recognition that pasture/grassland plants need to be monitored as closely as the livestock, and decisions made accordingly. The relationships between available forage and animal production are better known, and management decisions made using those relationships do lead to better overall animal performance. Those same relationships are also important when deciding to move livestock in grazing systems as weather conditions vary. As the amount of green and total forage declines, so will animal performance, and pro-active decisions can then be made rather than waiting until the plants and animals are visually suffering.

Utilisation and efficient vs maximum production?
Australian agriculture has evolved over the last two hundred years into systems that continue to improve the amount of saleable product from the available resources. With grasslands this involves improving the conversion of grass to animal product. That conversion needs to consider the levels of risk as we refine techniques to survive variable climates. The main risk is that grasslands will not survive if over-grazed. The level of forage that can be safely utilised so that grassland resources are sustained needs to be resolved for all regions and, especially, how that level of utilisation should vary with variable climates.

Utilisation is broadly the amount of grass grown that is consumed by livestock. This has major effects on the sustainability of the grassland. Forage crops are typically grown with the aim of utilising all the plant material grown. As a consequence, plants do not get the opportunity to replenish buds and reserves, and they typically die and need to be replaced. The same happens to heavily utilised pastures. In some dairying areas pastures may only survive for 2-3 years. High levels of utilisation are high-cost systems.

In contrast, natural systems in the rangelands need to be managed in a way that enables those plant communities to survive. It is important to maintain a high proportion of persistent, palatable, perennial (3P) plants, typically grasses. Because those plants are mostly under stress (typically moisture) they have limited opportunities to regenerate and can be damaged if over-grazed. In semi-arid Queensland, the recommendations are that only 20% of the forage grown in the wet season is utilised before the next wet season. Low levels of utilisation are important in other regions.

On the Canadian Prairies, where grasslands had been extensively grazed by bison before Europeans arrived, ecologists recommend that to ensure survival of the grasslands they be grazed once a year and 'eat half – leave half'. On the Prairies there is only a 100-120 day growing season and winter temperatures can reach -40^{o}C. Temperature stress can pose as large a problem as moisture stress. Similar conditions exist through the vast Eurasian grasslands that extend from eastern China to Hungary. High levels of utilisation are leading to increasing desertification during average seasons.

Aiming for 90% utilisation of the available forage would rarely result in the survival of many useful plants, unless those plants were very well adapted to the environment, and the grazing system provided opportunities for plant regeneration and restoration of reserves. Perennial ryegrass/white clover pastures in the Waikato region of New Zealand are regarded as the best in the world. It rains frequently there, farmers fertilise them well, and rotational grazing at times to optimise quantity and quality is practised. In this case, management enables flowering, seed set and regeneration to occur so that new plants replace the old ones naturally within the sward. If the level of utilisation is high then so needs to be the level of inputs – natural (e.g. rainfall) and applied by man.

We can construct a spectrum of responses where, as the productivity of a region/grassland system increases (e.g. if irrigated), so could be the level of utilisation, but so needs to be the level of inputs and so needs to be the requirement to re-sow. It is assumed in these considerations that the grassland species being used are the best adapted to the region. As productivity declines, the point where resowing is economically viable is soon reached, then at lower levels of productivity there is a progressive drop-off in inputs, e.g. irrigation, fertiliser, weed management, watering, fencing, etc.

Can we then use these general relationships to better manage grasslands within a variable climate? The dilemma created is that as rainfall and hence productivity declines, the grassland shifts in state from a higher to a lower condition, inputs are understandably reduced accordingly, but the effective utilisation increases when it should actually also be reduced if the grassland is to persist and to avoid costly resowing.

Figure 1 illustrates what happens in variable climates. If in an average year the pastures produce 10 t DM/ha then there are common characteristics that apply. In a drier year, where productivity declines to 5 t DM/ha or less, the pasture actually becomes something different and often needs to be managed differently. In this case, annual grasses may increase, legumes would decline in importance, and reduced farm inputs are required to sustain the system (apart from maybe weed control). One simple way of looking at this is that, in a drought, people on the tablelands need to think about managing their perennial pastures more like they would on the slopes or western plains. Utilisation rates (grazing pressures) need to decline, as the mainstay of such pastures (perennial grasses) will then have a better chance of survival. Unfortunately, the main problem as dry seasons develop is that utilisation rates effectively increase, putting above-normal pressure on pasture species that they are less able to cope with.

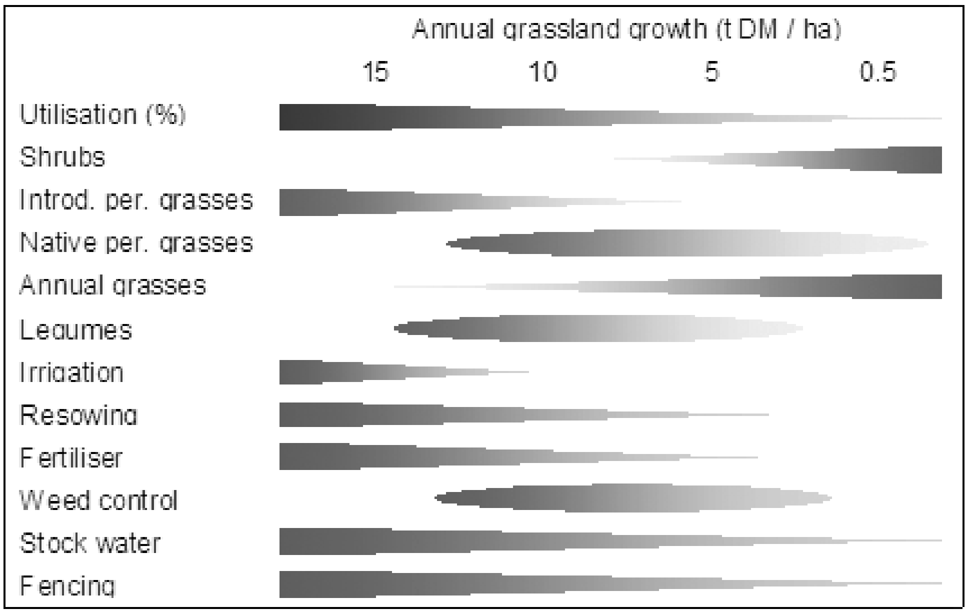

Figure 1. Generalised relationships between annual grassland productivity, proportion of forage utilised by livestock, proportions of plant functional types and inputs.

During a drought, 'over-grazing' obviously occurs as desirable plant species die out in paddocks, but not necessarily on the adjacent roadsides or in reserves. This suggests there is a tolerable level of utilisation for plant species even under stressful conditions; plants on roadsides are grazed by livestock and/or native herbivores, though usually at a low level. We have not yet developed consistent rules for management that help us determine what the utilisation level should be in relation to current plant growth conditions. In general, while it seems logical that for plant survival the proportion of plant growth consumed should decline as rainfall declines, we don't have a consistent set of rules that can apply in practice.

The general pattern of increasing utilisation of grassland as total productivity increases, within a region, breaks down as droughts occur, or even if the relative amount of rainfall starts to decline. Stocking rates are typically set by producers based on district and personal experience. That often means a stocking rate is set based on the animal numbers that can be carried through the average year. However, if rainfall is less than average, then the proportion of the grassland consumed by livestock obviously increases. This then puts the plants closer to where they could be severely affected by 'over-grazing'. As dry conditions develop and if stocking rates are not reduced, then utilisation rates would continue to increase until the point where plant losses occur. Unless management is sensitive to these risks, then there becomes an increasing probability that over-grazing can occur.

So how can we develop better rules for estimating at any time when the level of utilisation is appropriate or not? These are a few thoughts based on considering the broad range of conditions that may apply across southern Australia. Limited work has been done to quantify appropriate levels of utilisation. Ultimately it will be a matter of developing individual rules that apply on a property.

• When plants are actively growing, are well adapted to the local environment and they have time to recover after grazing, a high level of utilisation can be tolerated. High rainfall or irrigated temperate pastures in mild climates can manage high levels of utilisation e.g. 80-90%, provided they have time to recover between grazings.

• As dry conditions develop (not in a normally dry season, but during a period when rainfall would normally be expected), it may be wise to reduce grazing pressures early and not increase the amount of grassland being eaten.

• Try to define the absolute amounts of forage that need to be retained if grasslands are to survive. Observe what has happened during the recent drought and see if you can improve your own guidelines. Work at Carcoar within the Sustainable Grazing Systems program (Michalk *et al.* 2003) found that for Central NSW, leaving an average herbage mass of 2 t DM/ha through the year enabled desirable grass species to survive. Cocksfoot did decline as the drought developed, but then phalaris took over and the stability of the pasture was retained. In drier regions, a lower value may be appropriate. While Australian work has focused on managing herbage mass and/or plant cover as management guidelines, there hasn't been any local work to test the 'eat-half, leave-half' idea or some other ratio each time a grassland is grazed. This would build in a factor to account for variable seasonal growth.

• In normally dry seasons, consuming the dry forage is OK for annual plants, but removing all the dry material from perennial grasses can expose their growing points to desiccation and plant death as shown by Greg Lodge (at Tamworth) for phalaris. Dry material can act as a useful physical barrier that stops the growing points of plants drying out. In semi-arid Queensland as mentioned earlier, the recommendation is to only consume 20% of the dry forage left at the end of the wet season.

What plant types: native or exotic?

Since Europeans arrived in Australia there has been a perpetual search for new plants that can improve our utilisation of the landscape and resources available. Many productive species and ecotypes have been identified. For southern Australia, many of these plants came from around the Mediterranean, where they had evolved under lower-rainfall, seasonally dry conditions. However have these plants been useful during the drought? What has survived and what are the better ways forward?

An interesting shift in thinking and practice over recent decades has been an increasing interest in native grasses. This has been stimulated by the costs of resowing exotics, and the fact that some native species have persisted through tough times, actually re-invading previously sown paddocks. It may also be that native grasses seem to do better, because they occur naturally, they have involved lower cost to the producer (reduced production from these species means they would need less soil nutrients), and there is a reduced expectation of their carrying capacity, which means they are stocked at lower levels. We do not know if the physiology of native grasses is in any way radically different to the sown species from dry climates, but it is unlikely this would be the case. The survival of native species may relate more to the low level of utilisation that producers often apply. It would be a useful study to resolve the actual differences between native and introduced species.

In the more productive (higher rainfall/irrigation, higher fertility/fertilised) regions, sown introduced species have an obvious place, and species such as phalaris have survived reasonably well. In those cases the introduced species are arguably the more profitable. But as the potential productivity of an area has declined, so has the presence of many introduced grasses. Legumes are more variable, but subterranean clover, lucerne and white clover (in some regions) can be valuable contributors to production, provided they are fertilised. In general, the grass content of pastures seems to depend on management and rainfall, while legumes are driven much more by rainfall.

Twenty years ago many introduced grasses were being sown in areas where the annual rainfall is 500-600mm (in southern Australia), but today that is less so (unless soil fertility is high) and it is probably only areas >650mm that are considered for sowing. This is in part a reflection of increasing costs of sowing pastures relative to the often declining (real) returns from animal products.

Before sowing any pasture it would always be useful to do an analysis of the net profit and the likely productivity over a ten-year period including some low-rainfall years. This especially applies if resowing would involve replacing a grassland when the content of useful volunteer perennial grasses is say 20-40%. It may be that simply managing the pasture with grazing and fertiliser generates as much net profit as resowing, but with reduced risks.

Species and landscapes

Few paddocks are uniform and, in consequence, it is unlikely that any one plant species would be able to effectively exploit all the available resources. This has meant most paddocks will naturally contain a range of plant species and that sown pastures typically comprise a mixture of species. Recommendations to producers have focused on fencing and managing landscapes within more uniform sectors to reduce complications in management. A mixture of cultivars is not as efficient at exploiting available resources as a mixture of species. In effect, a mixture of cultivars is similar to sowing a native species that has not been selected.

The diversity of plant species within a paddock, arising from the mixture sown or naturally occurring, is often simply accepted and producers do their best to manage the mixture. Many producers are aware of how different species sort themselves out. Management is based upon what happens in average years. In drier years, species composition changes as some plants succumb to stress and are over-grazed, resulting in bare patches and then weed invasion when rainfall returns. These areas could be better used to monitor pasture management. If bare patches are emerging (e.g. in drier areas of a paddock), that can suggest the grazing pressure is becoming too high. If the bare patches remain small then that can often be accommodated, but if they expand then the costs of recovery after a drought are going to be significant.

What has never been well resolved is at what point should stock numbers/grazing pressure be reduced? This decision would depend upon the current likely benefits in terms of livestock income, the current costs in paddock management and the future costs and benefits of continuing to over-utilise the paddock *vs* a more conservative strategy. These decisions would also depend upon the financial resources of producers, and if they can defer some income to the future. At present such decisions are a bit of a guess, as one cannot predict the climate with a high level of precision, but being aware of all the consequences means that more informed decisions can be made.

Where paddocks are fenced on a landscape basis, then monitoring and management is easier than under highly variable conditions. As dry seasons develop, it is arguably the upper slopes where plant growth is most reduced, the risk of over-grazing and loss of desirable plant species higher, of weed invasion greater and costs of rehabilitation more likely. In dry seasons the actual animal production from the upper slopes is very limited. It could prove cost effective to use electric fencing or some temporary fence to restrict stock to lower parts of the landscape where plants are in better condition.

Species that are more important in drier parts of a paddock can also occur elsewhere throughout the paddock, e.g. *Austrodanthonia* spp (wallaby grasses) in natural grasslands. It can then be important to avoid over-grazing those species in more favourable areas so that they can survive, possibly expand during drier years and then when better conditions return, serve as a seed source to regenerate other parts of the landscape. The work being done on managing the natural recruitment of desirable perennial grasses within existing pastures is showing that there is almost no seed of those species in the soil seed bank and that recruitment does depend upon having a current seed source (Thapa, King, Badgery, Kemp, Lodge, Michalk, Dowling and others).

After a period of dry years, if scattered desirable plants remain, then they can be encouraged to flower and set seed to enable rehabilitation of the paddock. If they are gone then the expense of resowing is considerably more. The one good thing after a drought is that soil phosphate levels do naturally increase (Kemp *et al.* 1985) and, as a result, the need for fertiliser is less.

Wetter years

Mostly we are focused on what to do in a drought, but if management aims to accommodate average years, then there should be as many above-average and below-average seasons. Do we get the most from above-average rainfall years? Producers often express disappointment that they cannot obtain or afford to buy, extra livestock in good years, nor breed enough to take advantage of the season. However is this a bad thing?

Pastures need periods of recovery. Rotational grazing systems are designed to provide a period of recovery within normal grazing patterns. The typical cycle of years though, means that in drier periods it is difficult to avoid stressing the system, causing the loss of useful species and allowing weed invasion, bare ground to develop and resources to be depleted. When above-average conditions occur, this is an excellent opportunity for the more desirable species to recover reserves, flower, set seed and increase as the utilisation rate will have declined. Poorer paddocks can then be taken out of a rotation and allowed some recovery.

Plant breeding

The success of plant introductions, selection of better ecotypes/cultivars and breeding has meant there is good support for such programs. However one of the requests made of plant breeders is to select or develop plants that can be useful in droughts. It is doubtful if this could ever be achieved.

Plants require significant amounts of water to grow, develop and survive. If they do not transpire water they increase in temperature and cannot take up carbon dioxide for photosynthesis. Growth depends upon cells maintaining turgor, and even irrigated plants can wilt on hot, dry days as the flow rates of water through the plant are inadequate. Plants effectively 'shut down' under dry conditions to retain water within growing points, etc., but if then grazed, that water can evaporate and stress can occur. Desert plants are experts at retaining water and minimising the amount they need, but their growth rates are miniscule.

Attempts to breed plants that can grow without water are basically futile (Kemp and Culvenor 1994). What can be selected for are plants that can survive dry periods and this is helped by not over-grazing and exposing the growing points to dehydration. Retaining stubble helps. Plants can also be selected to recover better when rain falls. The annual legumes are very successful at this. Recovery of perennial grasses after dry seasons occurs from buds and from setting seed from which new plants establish. Tiller and bud density are characters that plants could be selected for, but they are also dependent upon how the plants are managed. A grass that is useful for grazing has to have a reasonably high tiller density which increases with optimal grazing strategies, provided there is water for growth. Seed production is a character that many plants are selected for. Seeds can be produced on limited water supplies (e.g. wheat crops in a drought usually produce some grain, even if it is uneconomic to harvest it). Managing the existing species and cultivars to ensure an adequate density of tillers and buds and their survival through dry seasons, and then resting paddocks to enable seed set, should then deliver the benefits required; arguably better than trying to breed super plants.

Discussion

Within agricultural communities there have always been livestock producers renowned for getting the best possible performance from their animals, through good and poor seasons. They often seem to have a heightened intuitive response to changes that others do not pick up; they reduce or move livestock at times that seemed strange to their neighbours. They make decisions almost in anticipation of poor seasonal conditions. As dry conditions developed their neighbours comment that 'Gordon' got it right again, and his stock and pastures are still in good condition.

In thinking about what these intuitive producers were doing, it seems that they were more sensitive to the state of their pastures and were monitoring criteria like herbage mass (green and total), relative to the levels required to sustain their livestock within the current season. They were not quantifying the levels of herbage mass and so could not necessarily tell anyone how they made their decisions. Other landscape clues would be important and would have figured in their judgements, such as water flows in springs and creeks, and changes in the botanical composition; legumes and forbs are more sensitive to water supply than grasses.

Research over recent years has brought together a lot of criteria around monitoring herbage mass (e.g. for livestock production, maintaining a desirable botanical composition, reducing erosion, etc). The current state of the art is that general (e.g. annual average or broad seasonal) values are now available, and they do provide much better guidelines for producers. Ground cover is a first step in this process and can be used as an initial criterion for management. During the first big 21st Century drought, many producers used these criteria to maintain their properties, animals and pastures in much better condition than in previous droughts. If the drought had only been for 1-2 years, then recovery would have been quick and less costly than is now the case.

What does need to be done is to achieve a better understanding on individual properties of the average herbage mass/botanical composition for each landscape type and season of the year, relative to the stocking rate where livestock production is optimal. When planning animal production, producers are often thinking of what is ideal. However as we go from good to poor seasons we need to clarify what is actually possible in each case, establish realistic animal production targets, determine what pasture conditions would deliver them, and then monitor how actual conditions relate to those realistic goals.

With targets in mind for each season, quicker decisions could then be made to move livestock before they start to fall behind. In some exceptional circumstances (e.g. a drier-than-average winter in southern Australia), the decision is often made to take a risk and suffer some short-term losses in the expectation that better conditions will return, and the livestock and pastures will quickly recover. However, the experience of recent years is that even the more reliable rainfall periods can fail, and it would have been better to have made decisions earlier. That brings us back to focusing mainly on making decisions relative to the current season and not being optimistic about future conditions, especially as in recent years the longer-term climate outlooks were not very optimistic. Climate forecasting is getting better and that will hopefully continue to improve.

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