A Users Guide to Drought Feeding Alternatives

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A Users Guide to Drought Feeding Alternatives

ISBN 1 86389 301 6

Typesetting and layout by Ian Kerr and Ilona Schmidt.

Printed by the University of New England, Armidale NSW Australia.

UNE
The University of
NEW ENGLAND

A Users Guide to Drought Feeding Alternatives

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Preface

A workshop entitled "A Users Guide to Drought Feeding Alternatives" was held at the University of New England in July 1995. The main objective of the workshop was to produce a publication which graziers and others would find relevant and easy to use. In order to achieve this objective the papers were prepared for publication with significant input from producers. Following the presentation of papers at the workshop the authors were questioned by the audience in a process led by a panel of producers together with an economist, Christopher Short from ABARE. In addition, all participants were asked to complete a questionnaire which provided further feedback to the authors. The authors were asked to prepare their final papers in the light of the comments and suggestions received during the Workshop. The papers were then refereed by three producer members of the panel before being prepared for publication.

The input of the producer members as Assistant Editors in this process has been particularly valuable. Our sincere thanks go to Guy Fitzhardinge, David Pratchett and Gordon Williams for their contribution. The meticulous work of preparing the papers for publication has been undertaken by Ian Kerr and Ilona Schmidt. Their enthusiasm and competence has contributed significantly to the successful completion of this publication.

The Workshop was made possible through financial support from the Meat Research Corporation, the International Wool Secretariat, the Rural Industries Research and Development Corporation and the Land and Water Research and Development Corporation. We are most grateful for their generous support.

We hope that the papers included in this publication will be useful for people as they develop plans to minimise the adverse effects of drought. We believe that it is only through planning ahead and taking advantage of strategies such as those described in this publication that we can utilise the resources available to us in an effective way and cope with the inherent variability in our climate.

James Rowe and Noel Cossins.

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Overview and Main Conclusions

Feeding strategies for production and survival

James Rowe and Noel Cossins

How to use this book

In this overview we have summarised the major conclusions which we believe emerge from the workshop. While there is no single simple recipe applicable for all producers in all years, there are a number of clear principles which will assist many producers to cope better with the next drought. This overview is followed by summaries of the key features of each paper which provide a rapid reference from which readers can move to the full paper(s) for detail of the various strategies which may apply to their situation.

How this workshop and proceedings differ from previous efforts

No one should plan a feeding strategy that is only aimed to guarantee the survival of stock. Drought feeding strategies should be an extension of production feeding strategies.

The main feature of this workshop on drought management, which distinguishes it from other workshops of this nature, is the fact that most of the strategies focus on feeding systems which offer the flexibility of targeting survival or production. These systems are suited to managing fluctuations in the availability of pasture feed which occur in normal years as well as providing options for coping with the extremes of drought. The ability to increase production in normal years and also maintain production, or limit losses, during drought can be simply based on resources available throughout Australia using information which we currently have. The essential component of all successful strategies is to recognise that drought is an integral part of Australian grazing systems. It is imperative that forward planning provides a range of options which are available at all times in order to cope with any extended dry period which can turn into a drought. By making long term plans adequate stockpiles can be conserved so that we can make use of the suitable feeds such as silage, cereals, cotton seed, lupins and molasses which we have in abundance in Australia.

The more traditional approach to drought management has been to turn to marginal feeds such as cotton trash, imported copra meal and sugar cane tops in an attempt to find short term solutions once the emergency has developed. Most publications on drought feeding have been written during droughts and these concentrate on least cost options for survival feeding. Making plans for drought feeding once the drought has started is a certain recipe for losing money and the paper by Thompson clearly illustrates this point. Under these conditions the producer has no control over any activity which can generate vital cash flow or alleviate the grazing pressure on scarce pasture resources. Money is spent on feeding which is not linked to productivity or the ability to generate income in the short or medium term. This management strategy has been supported by transport subsidies to bring in feed for survival feeding and has led to severe financial losses. Feeding grazing animals for survival also often means overgrazing large areas of land and the long term costs of overgrazing, hidden in the short term, will probably turn out to be the major cost of the drought. We believe that this is a totally inappropriate way to cope with the variability of the Australian climate.

Maintaining the pastures

Feeding strategies should be seen as a supplementary or supportive element to basic pasture and shrub production and not as a replacement.

The best return on planning and investment is likely to come from first optimising the management and use of pasture and shrub production. This is fundamental to the economic and biological sustainability of the grazing operation. Management of pastures for sustainable production and the introduction of deep rooted perennial forage shrubs offer long term strategies. The establishment of drought resistant shrubs and the regeneration of pastures requires adequate rainfall, and the appropriate time for implementation of these strategies is at the end of the drought. The papers by Scott and by Norton *et al.* cover these strategies. The variability in the climate will inevitably mean that at some times even good pastures and reserves of forage shrubs will not be able to supply adequate feed for optimal economic production. Under these conditions it is essential to preserve the key asset, good pastures, and avoid short–term overgrazing as an absolute priority. A rigorous stocking rate policy in combination with the use of conserved feeds provide effective tools to ensure the long term productivity of pastures and/or shrubs.

Knowing the weather patterns and long range forecasts

There is a gap between what the weatherman now knows and the information that currently filters down to most graziers. The odds are shortening but drought can still not yet be predicted with certainty.

In planning for and managing during droughts it is essential to have a clear and objective understanding of weather patterns and to make use of recent developments in long term weather forecasting. Computer programs are available which provide accurate unbiased information on the probability of rainfall during different times of the year for almost every region of Australia. This analysis of historical information, modified by long range forecasting, provides better data than we have ever had with respect to one of the most important aspects of decision making for all producers. This information on the weather is not yet widely used or well understood. The paper by Sparks will help producers who are not yet using the latest weather information properly to become more familiar with its importance and its potential application in planning for and managing drought.

What assistance can you expect from the government?

Except for social welfare payments for those really up against the wall, and some assistance for long–term planning, do not expect much else from government.

It is clear that government policy on drought is directed towards self sufficiency and planning for periods of lower than average rainfall. The current policy includes a combination of incentives and welfare/support measures. These are summarised by Munro and Lembit. Further analysis of the issues in the area of drought policy development are discussed by Simmons. The use of welfare payments was considered to be an unsatisfactory option by many producers but there were no specific suggestions of alternatives which were generally accepted by the workshop. Simmons pointed out that while there may be some scope to lobby for changes, it is most unlikely that the basic policy of greater self sufficiency will change significantly in the future.

What is a drought?

Any fool can create a drought, but sometimes even the most sensible stocking policies can be defeated.

The question of "what is a drought?" came up throughout the workshop and was largely left unanswered because there is a different answer for each farm. Feeding of livestock can be necessary and/or profitable whenever the amount or quality of pasture feed is below that which supports the desired level of animal production. The severity of a drought is determined by many factors apart from rainfall patterns and particularly by previous and current policies on stocking rate and pasture management. Successful management of drought depends very heavily on early decisions and flexibility which can only come from long term planning. A number of graziers quoted examples of farms in some regions being in drought through continued high stocking rates while their neighbours had adopted more conservative stocking rates or better pasture management and were not "in drought".

Management to minimise the risk of over stocking depends on knowing how much paddock feed is available, its nutritional value and the production it will support. When this information is used with an analysis of rainfall probability, and a prediction of how the available pasture will respond to rainfall at different times of the year, planning can be quantitative and strategic. Management of pasture resources using a quantitative and systematic approach provides the only basis for objective decisions on stocking rates.

To feed or to sell

Emergency feeding programmes generally cost more than they are worth.

If and when to sell livestock is one of the most difficult decisions facing graziers going into dry periods and droughts. The analysis by the Centre for Agricultural and Resource Economics (Thomson's paper) indicates that it is always more profitable (less costly) to sell stock rather than feed them in times of drought. This analysis is based on traditional feeding strategies using hay as the main drought feed and feeding for survival only. This is an analysis and a warning which all graziers should pay close attention to. It highlights the costs and the trap which many producers find themselves in when basing a program of supplementary feeding on the use of hay or "emergency" feeds such as crop residues (*e.g.* straw and sugar cane tops). At best these feeding systems, based on poor quality roughage, limit weight loss and stock do not finish or become more saleable. There is little or no flexibility with this system and once there has been a certain level of investment in the feeding of the livestock the decision to sell becomes very much more difficult. It is also likely that a long period of maintenance feeding results in damage to pastures and a reduced capacity for regrowth when it does rain. Both Scott in his paper and Barney Foran in his oral presentation emphasised the long term costs of damaging pastures and soil as a result of overgrazing during times of drought.

Feeding for maintenance or production

Feed for production, sell for survival.

One of the features common to practically all options was the range of benefits associated with feeding for production rather than for maintenance and survival. There is a wide range of feedstuffs which will allow the flexibility of feeding for production as well as for maintenance and this means that there is considerable scope to buy and sell commodities at the right prices.

Whatever supplements are used as the basis for feeding the most important basic principle is to maintain efficient rumen performance. The dominant role of the rumen in breaking down fibrous feeds and in producing protein for the animal has been acknowledged in all papers dealing with feeding strategies. Two major problems that the rumen may be faced with are insufficient nitrogen/sulphur for microbial fermentation and low pH (acidity) resulting from rapid fermentation of starch and sugars present in some supplements. Dramatic improvements in feed conversion and production result from overcoming N/S deficiency and the acidity associated with irregular grain feeding. In addition, problems of acidity associated with the use of cereal supplements, can now be reduced using virginiamycin (Rowe *et al.*) . Provided that efficient rumen function is achieved it appears that most non–roughage supplements including molasses, protein grains and meals, and cereal grains, can be used for production feeding. The papers by Lindsay, Henessey *et al.*, and Rowe *et al.* summarise these feeding systems.

The use of roughage based feed supplements have the disadvantages of high costs per unit of nutritive value for handling and transport. Hay, silage and straw do have an important role under some production systems where feeding for production is not necessary. These situations include feeding mature dry sheep to maintain wool growth and to maintain pregnant (non–lactating) cows in sufficiently good condition for reproductive efficiency. In papers by Dixon and Doyle on straw and crop residues and by Kaiser on hay and silage, there are details on the most effective way to use these feeds. Used in conjunction with supplements of grain, molasses or protein meal they can provide the basis for production feeding. The quality of the roughage is very important in determining how to use it on its own as well as the responses to using it with other supplements. Higher quality roughages have numerous advantages but the costs and practical difficulties of treating roughages to improve their digestibility makes this option of questionable value.

Hay and Silage

Forget hay and silage unless you produce them yourself.

Silage offers many advantages over hay as a drought feed. It can be stored for long periods and can therefore be used more strategically for drought feeding than hay. Its higher nutritional value also makes it a very good basal diet for production feeding when this is desirable. In many countries the use of contractors to make silage is a well established and cost–effective practice. There is scope to further develop the infrastructure to expand this practice in Australia.

We believe that hay and silage should be considered only as on–farm feed resources and a mechanism for transferring surplus feed available during particular times of the year, or during good seasons, to times when supplementary feeding is likely to be profitable. Hay and silage are important tools in managing pastures and can often be used more effectively to utilise surplus pasture than by purchasing additional livestock. The use of hay appears to have little value as a long term drought reserve or as a mechanism of moving nutrients from one part of the country to another. Its current popularity in this regard is mainly preserved by the transport subsidies rather than by its nutritional value or its benefits in drought management. Its popularity is further enhanced by the ease with which it can be fed out and its safety.

Shrubs and trees

It is time to give more thought to trees and shrubs in planning for the future.

The potential of using shrubs and trees to complement pasture production and as an alternative in some situations was presented by Norton *et al.*. As with pasture production shrubs appear to offer a stable, low–cost production system well suited to conditions of variable rainfall. Shrubs and trees have particular advantages in that their deep root systems make them more resistant to short term moisture shortage. The major problems with shrubs and trees are their utilisation in grazing management and/or harvesting, their establishment and the length of time before they can be used for production. Considering the relatively minor amount of research work done in this area in Australia, it is likely that there is still significant potential to develop the use of plants such as leucaena and tagasaste and to find other shrubs and trees suited to local conditions.

Welfare considerations

Land and animal starvation are linked and need not happen.

There are a number of strategies covered in this workshop which present benefits of feeding for production rather than survival. Excessively thin animals are invariably in the process of overgrazing land and endangering the long term productivity and sustainability of the country. Animals in very poor condition are also unlikely to be productive or profitable. The issues of animal welfare, sustainable land management and profitable livestock production are therefore closely linked. We believe that there are sufficient options and strategies available to producers for them not to have to operate under conditions where the welfare of animals or the sustainability of the land are compromised.

Opportunities for alliances and service industries

The single most important challenge for the immediate future is to develop integrated supplementary feeding systems which can be used to enhance profitability in good rainfall years and to support productivity in years of drought.

There are a number of feed resources which can be traded or used in a flexible and profitable way. We believe that every year should be treated as a potential drought year in securing feed resources through forward contracts and purchasing feeds at the most appropriate time when they are readily available. This only applies to those feeds which can be used profitably even in the absence of a drought or traded again if this emerges as a more desirable option. Although there may be costs associated with this approach it provides the opportunity to spread the risks across more than one industry.

Few producers can cope with additional activities such as monitoring a wide range of commodity prices, forward contracting, and selecting the appropriate feeds on the basis of nutritive value and price while, at the same time, managing complex grazing systems and other on–farm activities. Further development of the feed service industry has the potential to improve drought planning and management through sharing risks and expertise. An advantage for any livestock producer would be guaranteed access to feeds at prices which allow a profit margin when fed during normal dry periods and/or droughts. This can only happen if forward planning is combined with professional skill in purchase and use of feedstuffs. Skills and facilities are needed in the following areas: purchase and trading of feedstuffs; storage and insect control; least cost supplement formulation; feed preparation and mixing; and feeding equipment. This range of skills and infrastructure can be provided by the feed industry.

Alternatives to the feed industry taking an initiative in this area would include alliances between grain growers and livestock producers, forward contracts (as currently exist for molasses), or producer groups developing combined facilities and shared expertise.

There is currently limited development of complete feed services. A molasses–based feeding service is available in Queensland where livestock producers pay a single fee for a complete service including the provision of troughs and delivery of product. There are clearly opportunities to extend this type of service to other feed stuffs. It should also be possible to go further than a flat fee in terms of a price per tonne of feed and aim for charging on the basis of liveweight change. In fact payment on the basis of weight change would introduce the practice of weighing animals at regular intervals during the process of supplementary feeding and this, in itself, would improve management considerably. Buying feeds on the basis of the liveweight gain of grazing animals would place the onus of designing cost–effective feeding systems on the professional nutritionists and commodity traders. The producer would then be in a position to evaluate the supplementary feeding or drought feeding options in an objective way and have more time for the planning process which is so important. We often expect producers to make decisions on supplementary feeding which are extremely complex without appropriate information and infrastructure.There is a need and an opportunity for the feed industries to provide a more comprehensive service to help counter the adverse effects of climate variability.

Conclusions

If we continue to treat drought as an emergency, then grazing animals will remain as a cash drain during each drought and the land resources will take another step in the process of degradation. The results of this workshop suggest that when drought occurs there are only two sensible strategies for most graziers—to either feed for production or to sell. In this way, cash flow is generated and pastures are preserved. Any other prescription will only result in losses across the board. Some may read this book and end up by saying, "Well, what is new?". This will have some validity, although there are some new ideas presented, most of the papers deal with alternatives that have been with us for years. However, the key aspects presented in this book involve using the same ingredients but in ways which produce a different outcome. The challenge for the future is to treat drought as just one of the many components of any grazing operation. For this to be successful we must develop systems where the management of pastures and the supporting strategies for supplementary feeding can be easily adapted to ensure productivity during drought or to achieve enhanced profitability in more normal years.

Paper Summaries

By–pass proteins and associated technologies in drought
D.W. Hennessy, L.P. Kahn and R.A. Leng

- Nitrogen is the major limitation to efficient utilisation of dried, carryover pastures or stubbles that are offered to sheep and cattle in a drought. This especially applies to pastures during the 'dry' in the tropics, to those in the winter in the subtropics, or to pastures or cereal stubbles during the summer of mediterranean–type climates.
- Graziers need to cull unproductive stock and set liveweight targets for selected stock for particular management practices such as mating. Target weights are dictated by the need to maximise fertility for calving post–drought and to optimise survival rates in calves. Where they have plentiful dry feed, low in Nitrogen, they should consider micronutrient blocks that supply urea plus P and S as a lower cost option than protein meals. Some increase in fertility may be obtained by the small enhancement in protein nutrition from micronutrient blocks, even when changes in liveweight are small.
- Protein meals should be given in cases where no or very small increases in liveweight occur when micronutrient blocks are offered, and apparently adequate dry feed is available. The correct supplementation regime should be established by graziers for their breedtype in their districts for meals that are price competitive. There is a generalised prediction equation in this paper which may be used to predict supplementation rate for expected gains. Protein meal prices are determined by supply/demand factors in Australia and other countries, especially U.S.A. Manufacturers will sell overseas when the price differential is favourable, hence those graziers who supplement annually should make forward-contracts to buy meals at lower prices than occur during droughts.
- British Breed cattle apparently require supplementation with a protein meal at greater rates than *Bos indicus* cross cattle in Australia. Within any breedtype, first–calf heifers have the greater requirement for supplementation and even then it is difficult to induce oestrus in young heifers.
- Troughs are required for the feeding out of meals; allow space to reduce 'bullying'. Animals fed previously will be the first to commence feeding during a drought. Bullying can be reduced by

feeding the weekly allocation on two separated periods in the week without a loss in production when feeding meals that have a moderate to high 'bypass' protein component. Such meals include cottonseed meal, meat meal, copra meal and treated sunflowerseed meal. Do not store meals in silos much beyond 6 months because of deterioration and clumping of the particles.

- Pelleting can improve storage life, and pellets are easier to handle, eliminating the need for troughs with feeding–out onto the ground; these advantages often justify the higher cost.

Cereal grains and energy supplements for drought feeding

J.B. Rowe, G. Thorniley and M. McDowall

Cereal grains offer a cost effective source of supplementary feed for maintenance or production but their use is often limited by the difficulty and danger of feeding them to grazing sheep and cattle. While cereal grain is more expensive and not as readily available when most needed in severe droughts, it still tends to be more accessible and cheaper than other supplements such as protein meals and legume grains. Protein supplements provide similar, or even better responses than cereal grains without the dangers associated with cereals. Because of the safety of feeding protein supplements and the perceived benefits of additional protein these supplements are also consistently and significantly more expensive than cereal grains.

Comparisons between cereal grains and protein supplements are not easy to make because the difference between these two types of supplements includes the presence or absence of starch as well as the amount of protein which they supply. The presence of starch can have a negative effect on the animal through rapid fermentation in the gut which leads to reduced fibre digestion and the accumulation of acid which can cause low gut pH and acidosis. The compound virginiamycin (sold as Eskalin™) reduces the risk of acidosis and overcomes many of the adverse side effects of feeding grain. The use of virginiamycin to make it safer to feed cereal grain provides more flexibility in the choice of supplement. Once the adverse effects of starch are overcome, using virginiamycin, cereal grain can be just as good a supplement as more expensive protein supplements in most situations. The use of grains with virginiamycin as components of balanced supplements in conjunction with non-protein-nitrogen, true protein and minerals requires more work, but is theoretically the most flexible and cost effective option available for feeding cattle when the nutritive value of paddock feed is limiting.

Production feeding even in times of drought offers many advantages compared with feeding for maintenance and survival. Feeding grain rather than hay or other low quality roughage provides the opportunity to finish cattle and sell them at a premium price. This option maintains cash flow at a difficult time by feeding to convert almost unsaleable cattle in store condition to marketable finished cattle. A second benefit is that selling cattle also reduces the overall grazing/stocking pressure. On the other hand, feeding for maintenance or survival in a drought is a risky option which can only be justified when sheep are being managed to produce a quality fleece, when valuable female animals are being managed to maintain reproductive efficiency and when young animals are being supplemented for survival. Even in these situations selling and repurchase is often more cost effective.

It is far easier to buy, store and sell grain than is the case with hay or silage. Cheaper feed grain or weather–damaged grain is almost always available around harvest time but livestock producers do not often have the infrastructure to take advantage of this fact. Purchase and storage of grain requires some capital infrastructure in the form of silos, augers *etc.* and the availability of cash for purchasing a commodity at a time of the year when it is often not seen as an essential requirement. It also requires some technical expertise and experience in storing the grain and maintaining it free of insects without creating any pesticide residue problem when the grain is fed out. While there are a number of mixed farms producing both grain and livestock there are a far larger number of producers who specialise in either cropping or livestock production. In the case of specialist producers there is considerable scope for developing strategic alliances between grain growers and livestock producers in order to spread the risks and benefits of commodity price changes across grain, beef and wool. Once the grain is on hand it can be fed through sheep or cattle or sold for alternative uses if this option brings a greater return. In order to retain this flexibility the grain needs to be stored well and must be easy to handle. Livestock producers and grain traders can also develop arrangements based on forward contracting as is currently possible in the case of molasses.

The nutritional value of cereal grains can be enhanced considerably by addition of non–protein nitrogen (urea), minerals such as calcium and small amounts of protein in some situations. It is also cost–effective to process cereal grains before feeding them to cattle. The cost of processing is considerably reduced by economies of scale and the use of appropriate equipment. When considered together with the logistics of buying and storing grain there are some important benefits which emerge in favour of larger scale centralised grain handling and processing facilities. This opens up the possibility of providing a complete feed service industry whereby feed, feeders and the job of feeding out are all covered in a single price as $/day to achieve a set objective or $/kg liveweight gain. While there is a developing industry in protein meals this has not yet extended into feeding systems based on cereal grains. As we understand how to use cereal grains more safely and effectively there is increasing scope to develop more flexible and cost–effective feeding systems for production and survival of livestock during drought.

Accuracy of climate forecasting

E. Spark

The variation of weather and climate takes place on a number of different time scales. The shortest of these are regarded as weather. The longer variations are known as climate—the longest of these occur on the scale of centuries or more. Our capacity to forecast climate is dependent on the time scale being considered. There are significant parts of the climate system, such as variations on the order of decades, which are poorly understood and for which there is currently no forecast capacity. On the other hand, two areas of climate which enjoy great current interest and research are the El-Niño-Southern-Oscillation (ENSO) which occurs on a time scale of one month to a year and 'Enhanced Greenhouse' which may occur on the time scale of centuries.

This paper explains some of the variability that is found in our climate records and explains the mechanisms leading to ENSO. ENSO is particularly important to the rural industry, because it explains, and allows the possible prediction of the occurrence of a large number of our drought and flood years. Current methods leading to El–Niño related climate predictions are based on historical correlations rather than physical prognostic models. Such prognostic models are being developed and should be available for forecasting purposes in perhaps five years.

The place for molasses in drought feeding strategies

J.A. Lindsay and A.R. Laing

Molasses has been used as drought feed for one hundred years. It is an energy supplement and needs to be balanced with protein meal or urea and sometimes salt and phosphorus. A simple, effective supplement is molasses and 8% urea to maintain weight and a mix of molasses, 3% urea and 8 – 10% protein meal will ensure weight gain. The supplements are cost–effective in areas within 500 – 800km of sugar mills. Molasses supply is stable and production from the mills coincides with times of peak demand.

Molasses is the basis of an effective and cost–effective drought feeding programme. The system is simple and easily managed on property. There is moderate capital investment in farm storage and a mixer. This investment can be used to value add cattle when drought conditions are absent.

Straw and low quality roughages as drought feeds

R.M. Dixon and P.T. Doyle

Cereal crop residues and dead mature pasture are often the primary feeds available to maintain stock during drought. Although of low nutritional value, their advantages are in their availability and in most circumstances their low cost. Costs for baling and transport may make straws more expensive per unit of metabolizable energy than grain or molasses.

On farms with abundant roughage of low quality, the principle issue becomes how to utilize this roughage most effectively. On farms with a shortage of any feed, the principle issue will usually be to estimate the nutritional value (particularly of energy) of the available roughage compared to purchased feedstuffs.

Constraints on the use of straw and dead mature pasture include the need to avoid over-grazing, low nutritive value and low voluntary intake, and high costs for baling, transport or chemical treatment to improve nutritional value.

Nutritive value of low quality pastures and cereal crop residues varies widely. Leaf content of straws is usually the most important characteristic determining their value. Most crop residue is utilised by grazing the stubble. Intensive selection of the more digestible parts of the stubble means animals are likely to maintain liveweight (LW), for some weeks or months after being introduced to stubbles. However, later LW losses may be severe. Availability of small amounts of green plant material from storms has a major effect on the productivity of animals grazing stubbles.

Supplements based on non-protein (urea) nitrogen and sulphur (NPN/S) can reduce rates of LW loss and improve reproduction rates of animals grazing stubble or dead mature pasture. Little response to NPN/S supplements may occur if:

- The quality of ingested roughage is adequate due to selection;
- Animals cannot select roughage high in leaf; and
- difficulties with delivery of supplements results in many animals consuming little supplement or there is poor synchrony of supply of substrates in the rumen.

The value of NPN/S supplements is principally to reduce mortality and to delay the need to implement alternative higher cost feeding and management strategies.

Pasture management and stocking rate policies

J. Scott

Productive pastures are the most cost–effective source of feed for livestock, producing feed at a discounted cost of from $30/tonne down to $10/tonne if they persist for more than 3 years or 10 years respectively; this is far more economic than bought grain ($325/ tonne) or hay ($160/tonne).

Many graziers have 'lost the plot' with their pastures by undervaluing their capacity to deliver quality feed at a low cost, provided that adequate inputs are applied to balance prior exploitative practices. Opportunities for increasing returns are also missed when the pasture base is in such poor condition that it barely grows when favourable conditions do occur.

Droughts are not new phenomena. Farmers need to be able to adjust to drought with flexible management and prudent tactical decisions in the face of risk. Valuable pasture plants are lost due to the dual stresses of drought and grazing. Drought management research on the Northern Tablelands of NSW has shown that perennial grasses, if grazed hard, can die even in commonly experienced dry periods, not just those drought periods which are extreme. More moderate grazing of grasses subjected to drought leads to greater energy reserves for regrowth and thereby greater survival. Hence, there is a need, during drought, to lessen grazing pressure on pastures if they are to survive and thereby protect prior investments and be capable of rapid growth when conditions improve.

Stocking rates can and should be adjusted, both property wide and in individual paddocks, as the need arises. Graziers should be aware that there is no optimum stocking rate—stocking pressure needs to be varied along with conditions. Yet, grazing pressure is one of the key determinants of pasture productivity, persistence, botanical composition and thereby animal productivity and profits.

A wide range of pasture management options are briefly outlined and the point is made that many of these need to be used in conjunction with each other if overall pasture management is to be successful.

For future sustainable systems, graziers need to embrace flexibility, diversification, an ability to capitalise on good times by developing their natural capital (including soil, pasture and animal capital) as well as financial capital, such as off–farm investments.

Livestock enterprises based on grazed pastures are long-term ventures. The benefits to be reaped from well managed pastures may not be immediately apparent but are substantial over the long–term. Some suggestions are given for how we might learn to drive these complex grazing systems by developing decision tools which are powerful and yet intuitive to use.

In terms of the reference framework for this workshop, long–term pastures are seen as a highly desirable feeding strategy for livestock in drought because:

- Animals harvest the feed themselves without the inefficiencies brought about by having to harvest, transport and store the feed;
- The cost per tonne of feed is dramatically lower than that of bought grain or hay;
- The potential for introducing pests, weeds or residues is minimised;
- Animal welfare considerations can be minimised by de-stocking before serious weight loss;
- Animals are able to select a diet superior to the gross herbage quality through selective grazing; and
- No government incentives are needed—merely an appreciation by the grazier of the cost effective nature of investments in productive and persistent pastures.

However, there is a need to understand 'whole' grazing systems if sustainability is to be attained. Future work needs to identify ways in which farmer decision making in a risky environment can be improved.

Pasture and forage crop conservation—hay and silage
A.G. Kaiser, J.L. Jacobs and B.L. Davies

Forage conservation is an important drought strategy available to producers in many regions of Australia, except in the low rainfall rangeland environments. Pasture is likely to be the most important resource available for hay or silage production, but in many areas forage crops will be a better option because of low or unreliable pasture yields and lower pasture quality.

Although Australia produces 5.43 million t hay and 0.85 million t of silage per annum (1991-93) this is not a particularly high level of production if it is compared to our combined cattle and sheep population. For example, if we were to feed our annual hay and silage production at the maintenance level of feeding to our entire cattle and sheep population it would provide only approximately 21 days feed. Most of the conserved forage is produced across southern Australia, there being little forage conservation in the north. In non-drought years average annual hay use has been approximately 94% average annual production so only a low proportion is set aside as a drought reserve. From the above discussion it is clear that there is considerable potential to increase the production of conserved forages in Australia, not only for drought but also for seasonal supplementary feeding and for production feeding purposes.

The paper briefly summarises the more important forage conservation principles, contrasting the differences between hay and silage. The reduction of field and storage losses have an important impact on the cost of hay and silage production. With good management field losses, both in terms of the quantity of forage lost and the reduction in forage quality, are lower with silage particularly during wet weather when hay losses can be very high. Storage losses can be a little higher for silage systems when compared to shedded hay, but they are lower when compared to hay stored outdoors.

Feedout management can have a significant impact on forage losses, animal performance, feed costs and profit. Feeding hay or silage on the ground can result in up to 50% wastage. The use of ring feeders can significantly reduce these losses and improve animal performance. Other important feedout management issues discussed are baled silage vs. conventional chopped silage systems, the importance of chop length on intake and animal production, and the aerobic spoilage of silage. In a production feeding situation the system used to feed out baled hay or silage could be important. Feeding bales in self-feeders or ring feeders could influence forage intake. It may, for example, be necessary to restrict the number of animals sharing a self–feeder and chop the silage if maximum intake and animal production are to be achieved.

The quality of conserved forages determines the potential animal production that can be achieved from each tonne of hay or silage. It therefore has a major impact on the profitability of forage conservation. Hence targeting high quality is one of the most important management principles when producing hay and silage for both production feeding and drought feeding purposes. Cutting forage early, when quality is higher, is the most effective strategy to produce a high quality product. This is more difficult to achieve when making hay. Hence silages are generally of higher quality than hay. High quality silages will sustain high growth rates and can be used as the major feed component in finishing diets for cattle and lambs.

Apart from its prime role in providing additional feed, forage conservation can also be used as a pasture management tool leading to improvements in pasture utilisation, stocking rate, pasture production, legume content, weed control, and pasture quality. These benefits have not been included in economic analyses but could have a major impact on the profitability of forage conservation. In addition the use of legume-based forage crops for silage production in cropping areas could improve the nitrogen supply and reduce weeds and disease in subsequent crops.

Current Federal Government drought policy is to encourage greater self reliance among livestock producers. However, although forage conservation would be an effective drought strategy in most environments, previous attempts to encourage producers to conserve forages for drought have not been particularly successful. We believe this is because forage conservation has been promoted for drought alone and because producers regard it as a high cost strategy (the cost of forage conservation is discussed in the paper). A better approach would be to promote its economic benefits for production feeding and pasture management (and crop rotations) with drought feeding as an additional goal. This approach, together with supporting research and extension programs and selective financial incentives to defray the cost of equipment, should increase adoption.

Beyond the herb layer—shrubs and trees as drought reserves

B.W. Norton, R.C. Gutteridge, P.W. Johnson, I.F. Beale, C.M. Oldham and D.M. McNeill

Although it is recognised that pasture is the major feed resource for grazing animals, trees and shrubs also contribute to the diet selected by stock in most environments. Once established, the deep rooted nature of trees and shrubs makes them more resistant to water stress than pastures, and this attribute may be used to provide additional feed for stock during drought. Edible indigenous trees and shrubs represent a natural fodder bank in Australian grazing systems, but are more often exploited rather than managed as feed resource. However it is now being recognised that trees contribute significantly to landscape stability and the long term sustainability of pastoral systems. This review paper explores the present use of trees and shrubs in Australian grazing systems and concluded that with the exception of mulga *(Acacia aneura)*, there are few indigenous trees managed as a drought reserve. Whilst there are other indigenous trees which are palatable to stock (Kurrajong, Saltbush, Wilga), their infrequent occurrence and slow growth makes them of limited value as a significant drought reserve. Many exotic trees have been introduced to Australia since settlement, but only two species, leucaena *(Leucaena leucocephala)* and tagasaste *(Chamaecytisus palmensis)*, have been successfully introduced into commercial grazing systems. It has also been noted that whilst there appears to be many new trees and shrubs which may be useful in sub-tropical and tropical environments (Calliandra, Albizia, Sesbania, Gliricidia), there are only a few (tagasaste, Robinia, willow) with similar potential for southern Australia with its predominantly mediterranean environment. Information on the establishment, management and productivity of mulga in western Queensland, tagasaste on the sandplains of Western Australia and leucaena in central and northern Queensland is discussed in the paper. Additional recommendations for use can be obtained through the relevant departments of agriculture in Queensland, New South Wales and Western Australia.

An approach for analysing financial viability and risk on farms

D. Thompson

The National Drought Policy is aimed at developing self–reliance amongst farmers in terms of their response to climatic variability.

In this study, the RISKFARM model has been modified to examine the financial and risk implications of following common drought preparedness options. This has been done within a framework which acknowledges that drought risk is a subset of the total farm risk portfolio.

Many of the drought options examined represent longer term decisions for dealing with drought. These are compared to more reactive, short term tactical responses where the farmer is forced to act. The study method involved considerable interaction with farmer/ farm adviser consensus groups to capture the key financial/physical and drought management parameters for a range of farming systems.

The financial outcomes generated were of a probabilistic nature, allowing comparisons to be drawn on the basis of both the level and variation in financial performance. In general terms, results indicated that where drought (or other adverse circumstances) last several production cycles, both management and taxation options would do little to offset poor financial performance. Some management options outperformed others, but overall the improvements were small relative to the possible range of financial outcomes.

While traditional management strategies appear to cope well with expected climatic variation, the scope for responding to severe drought appears limited, indicating that making the most of good seasons, limiting losses in poor seasons and access to off–farm income may be the most robust drought preparedness strategies.

Several taxation options (tax averaging, income equalisation deposits/farm management bonds and livestock elections) were also investigated. The general conclusion is that using one tax smoothing instrument can provide substantial financial benefits, adding extra instruments to the portfolio provides little additional benefit. Since most farmers use tax averaging, it would appear that most financial gain can be extracted from concentrating on drought management options, as opposed to tax management.

Results also indicate that combinations of other moderately adverse conditions (*e.g.* below average prices and yields combined with higher interest rates) can be as financially devastating as prolonged drought. There is a need to treat farm risk in a total, rather than a partial manner. The RISKFARM model can be used to identify key farm risks as a step toward a more cost-effective risk management plan.

Current commonwealth drought policies

R.K. Munro and M.J. Lembit

The National Drought Policy was agreed to by the Commonwealth, State and Territory governments in 1992. The current drought has seen the policy put into practice and highlighted the need for adjustments to policy settings. The Commonwealth has made a number of adjustments which have resulted in a more complete policy which provides support targeted at farmers in all economic groups. Profitable farmers are encouraged to prepare for future droughts, farmers who are unprofitable in the short term are provided with assistance to carry on their businesses and farmers unable to meet everyday living expenses are provided with welfare assistance. The Commonwealth's long term goal is to encourage a self reliant industry which manages the risks inherent in farming, reducing the likelihood that farmers will have to access welfare type assistance.

Bypass Proteins and Associated Technologies in Drought

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Summary

- Nitrogen is the major limitation to efficient utilisation of dried, carryover pastures or stubbles that are offered to sheep and cattle in a drought. This especially applies to pastures during the 'dry' in the tropics, to those in the winter in the subtropics, or to pastures or cereal stubbles during the summer of mediterranean–type climates.

- Graziers need to cull unproductive stock and set liveweight targets for selected stock for particular management practices such as mating. Target weights are dictated by the need to maximise fertility for calving post–drought and to optimise survival rates in calves. Where they have plentiful dry feed, low in Nitrogen, they should consider micronutrient blocks that supply urea plus P and S as a lower cost option than protein meals. Some increase in fertility may be obtained by the small enhancement in protein nutrition from micronutrient blocks, even when changes in liveweight are small.

- Protein meals should be given in cases where no or very small increases in liveweight occur when micronutrient blocks are offered, and apparently adequate dry feed is available. The correct supplementation regime should be established by graziers for their breedtype in their districts for meals that are price competitive. There is a generalised prediction equation in this paper which may be used to predict supplementation rate for expected gains. Protein meal prices are determined by supply/demand factors in Australia and other countries, especially U.S.A. Manufacturers will sell overseas when the price differential is favourable, hence those graziers who supplement annually should make forward-contracts to buy meals at lower prices than occur during droughts.

- British Breed cattle apparently require supplementation with a protein meal at greater rates than *Bos indicus* cross cattle in Australia. Within any breedtype, first–calf heifers have the greater requirement for supplementation and even then it is difficult to induce oestrus in young heifers.

- Troughs are required for the feeding out of meals; allow space to reduce 'bullying'. Animals fed previously will be the first to commence feeding during a drought. Bullying can be reduced by feeding the weekly allocation on two separated periods in the week without a loss in production when feeding meals that have a moderate to high 'bypass' protein component. Such meals include cottonseed meal, meat meal, copra meal and treated sunflowerseed meal. Do not store meals in silos much beyond 6 months because of deterioration and clumping of the particles.

- Pelleting can improve storage life, and pellets are easier to handle, eliminating the need for troughs with feeding–out onto the ground; these advantages often justify the higher cost.

Introduction

Characteristics of forages in drought

In the early phases of a drought there is, in general, sufficient amount of forage available to grazing stock but this forage tends to be fibrous, relatively high in ligno–cellulose and low in soluble sugars. In most cases it is of low digestibility and often deficient in some critical nutrients that are required by the animal either singly or in combination including protein, non–protein nitrogen and specific minerals. The forages available in prolonged dry seasons in the tropics and sub-tropics often have more exaggerated deficiencies of nitrogen (*i.e.* protein) and minerals and are of lower digestibility than temperate forages. The only time that dry pastures may support high levels of production is when they dry off in their leafy growth phase and stocking rates are low so that animals are able to select leaf material higher in protein/minerals and digestibility than the stalk or whole plant.

Low growth rates of cattle on drought affected forages are usually less than 10% of the genetic capacities of the various cattle breeds, and are largely associated with a low efficiency of feed conversion to body weight gain or milk production. It is necessary, when discussing supplements for ruminants grazing dry pasture available in short–droughts, to identify the constraints and the target levels of production to be achieved. In general, the primary constraints to animal production are low digestibility of forage and the poor efficiency of utilisation of nutrients that are available to the animal.

This paper, therefore, refers to the utilisation of dry pastures that are available during the first phase of a prolonged drought or to those pastures available during the seasonally expected dry seasons in pastoral areas of Australia.

Nutritional value of low quality forages

The nutritional value of forage is often categorised from the crude chemical composition of the forage and its calculated metabolisable energy content. The latter is often obtained by extrapolation from laboratory measurements on the digestibility of forage. Although measurement of digestibility and analyses that indicate cell solubles and cell wall materials are highly useful for studying the fermentative characteristics of a forage, they often bear little relationship to its feeding value. Feeding value is determined by the efficiency of feed utilisation rather than the metabolisable energy intake *per se* and such an efficiency takes into account the characteristics of the animal as well as the plants and the balance of nutrients in the diet. Efficiency of feed utilisation in ruminants is therefore dependent on two conditions:

- The balance of nutrients available to the microbes that constitute the digestive system in the rumen; and

- The quantities and balance of nutrients available to the animal from the digested feed in relation to requirements.

In this discussion the overriding effect on efficiency of production of balancing nutrient availability to nutrient demand is emphasised as part of a drought feeding strategy. This usually means that, with ruminants on dry forage, dietary supplements have to be planned to ensure that a desirable ratio of protein is digested in the intestines relative to energy made available from the acids produced in the rumen.

Priorities

To optimise ruminant nutrition on a particular feed resource a number of well tested strategies are available. Undoubtedly, purposeful supplementation with or without manipulation of the digestibility of forage can result in surprisingly high feed conversion efficiencies and levels of production in ruminants never before thought possible (Leng, 1990). However, it is not always feasible to achieve these strategies simultaneously. It is important, therefore, to recognise the primary constraints to ensure logical progression in supplementation strategies in a particular locality and with the local forage resources available in drought.

Ruminants Grazing Dry Pastures / Stubbles / Given Poor Quality Hay or Straw

The priorities in a supplementation strategy are:

Priority 1—ensure an efficient microbial digestive system in the rumen which ensures maximum digestibility of forage–generally achieved by supplying a multi–nutrient mixture of urea, minerals and some protein/energy;

Priority 2—ensure an optimum balance of nutrients to meet the animal's requirements as precisely as possible. The balance must consider protein to energy required to meet the productive demands of the animal, the nutrient requirements imposed by hot/cold, the environment and the demands for nutrients for work. It also requires that the grazier has a target weight for his animals to be achieved at a precise time in the future; and

Priority 3—ensure this balance is optimal for the rumen ecosystem, thus reducing the need for bypass protein. This is a continuation of the first priority, but is achieved by supplying nutrients for the rumen microbes at optimum concentrations and continuously over a 24 hour period where possible.

It is only when the constraints implicit in these three priorities are at least partially overcome that there is good reason for applying technologies to improve the energy density or digestibility of the basal feed resource or to provide extra, fermentable carbohydrates. Increasing the digestible energy density of a feed may be achieved by treating the feed resource prior to feeding the animal (*e.g.* ensiling of straw with urea) or by supplying energy feeds by supplying such as molasses, grains or whole cottonseed and recognising the substitution effects of these energy sources.

Approaches to realise efficient forage utilisation

Availability of Critical Nutrients

Under the anaerobic (without oxygen) conditions of the rumen, the optimum efficiency of microbial growth realises a ratio of protein (P) derived from microbes, to energy (E) derived from organic acids, namely volatile fatty acids (VFA) termed the P/E ratio, of about 34g protein/MJ of VFA. The efficiency of microbial growth and the P/E ratio are, however, related to the availability of the least–limiting nutrient for the specific microbes present. On any diet this might be a macromineral, a trace element or a non protein nitrogen source *e.g.* ammonia. The actual requirements will depend on the microbial ecosystem which in turn depends mainly on the major carbohydrate component of the forage.

There will be a critical level of a nutrient in a diet below which microbial growth efficiency in the rumen will be decreased to the extent that the size of the rumen microbial pool is reduced. Progressive correction of deficiencies of ammonia and minerals will improve the microbial growth efficiency and therefore will optimise the P/E ratio in the nutrients absorbed; for example, the P/E ratio might be as low as 8-10g protein/MJ VFA because of a mineral (*e.g.* P, S) or ammonia lack, and the digestibility and intake of the forage will be lower. When this is corrected with supplements this moves to 34g protein/MJ of VFA. Thus nutrient availability from poor quality forages for the ruminants is low and, in addition, the balance is below that required at times for maintenance of the animal. This can be improved at low cost with a multinutrient mix aimed at increasing microbial growth in the rumen.

In the past, the effect of increasing the P/E ratio in the nutrients absorbed appears to have had two effects. These may have acted singly or together on the nutrition of the animal. These effects are:

- **Effects of supplements on intake and efficiency of dry feed utilisation**

  Most of the early work on supplementation with urea molasses blocks and bypass proteins to improve the P/E ratio indicated large effects on voluntary feed intake of ruminants fed low protein forage. This appeared to explain the increased production responses. However, some results indicated that whilst molasses/urea multinutrient blocks (abbreviated as MUMB) improved forage intake, the provision of bypass protein either with molasses/urea mixes or fed alone, did not further effect forage intake. This was confusing, because the stimulation of voluntary intake by protein supplement appeared to be contrary to the theories of appetite control of ruminants which has distension of the rumen playing the most important role in low quality forage–based diets. The effects of bypass protein supplement on forage intake appeared to be related both to the efficiency of feed utilisation and to the bulk distension of the rumen. Unfortunately, many feeding trials have been undertaken under group feeding conditions in which estimates of forage intake were not made; thus it is often not easy to differentiate the contribution to increased growth of total feed intake or efficiency of feed utilisation.

- **Effects of supplementation on ruminants on dry feed in hot environments**

  An explanation for the different feed intake responses to the availability of standing feed becomes critical to our understanding of nutrient requirements of ruminants. A possible explanation for the differences resides in the fact that many ruminants appear to be highly sensitive to heat stress. Evaporation of water from perspiration from the body surface is the major physiological method of cooling, but the ruminant has only 0.2 of the capacity of man to dissipate heat by this route. They are, therefore, highly sensitive to any heat load if they are in a hot/humid climate. Similar heat sensitivity might occur if they have a highly insulative coat in a moderately warm climate, and/or have a high metabolic rate following introduction from a cold environment into a warm animal house.

It is suggested that supplementation of cattle with a bypass protein stimulates intake of low quality forage when animals are under heat load and have already reduced intake in the unsupplemented state to accommodate this stress. The theory is that a metabolic heat load reduces feed intake when the animal is in a climate where this extra heat cannot be dissipated by evaporative cooling. This reduced intake is ameliorated by balancing nutrients to the animal's needs by supplementation.

Overview

The overall observation is that unsupplemented ruminants on poor quality feeds are more adversely affected in hot times by deficiencies of nutrients than animals in temperate areas under equivalent conditions. The absolute response depends on the breed, although the response to supplementation is greater in animals in the tropics partly because these animals are at a lower base level than those in temperate areas.

In conclusion, feeding urea/molasses blocks with low quality forages usually improves digestibility and intake. Adding extra protein as bypass protein may have a variable effect on intake depending on location, but will generally further improve animal production.

Application of supplementation to balance P/E ratios

The principles of feeding bypass protein to improve productivity have been known for many years, yet the application has been slow and unspectacular until the present series of droughts.

The application has been slowed by:

- The inability of research scientists and extension workers to communicate effectively with the producers involved;
- The controversies surrounding the mode of action of protein supplementation; and.
- Unfamiliarity with supplements resulting in some animals' not accepting them or having variable and often inadequate intake.

However, increasing use of supplements such as MUMB and bypass protein have been promoted in Australia through the initiatives of the feed compounding industries. These have set out to manufacture appropriate blocks or pelleted feeds and, where necessary, to install the appropriate treatment to produce bypass proteins. Cottonseed and linseed meals have been recognised as by–product meals with high escape protein characteristics, whereas sunflower, canola, soyabean meals are now being treated to reduce their rather high solubilities and provide a high proportion of bypass protein for ruminants.

Molasses/Urea Multinutrient Blocks

Undoubtedly, when ruminants are on dry feed, there is a constraint set on the feed value by efficiency of microbial growth in the rumen, by a lowered intake of feed due to reduced digestibility and often by a heat load. This has been recognised for a number of decades. In general, it is known why responses occur to molasses/urea blocks in grazing animals but often the correct time for feeding blocks in the drought or dry season is unknown. Cattle are less selective of pasture plants than sheep and responses become obvious early in the dry season; but with sheep any reaction to blocks may be delayed because of the ability of sheep to select green (high protein) feed and maintain a higher quality intake into the dry season.

Animals using molasses/urea blocks will eventually learn to adjust their intake of block to ensure an optimum functioning rumen. It is appropriate to use molasses/urea blocks early in the season to allow animals to get accustomed to them, to learn to regulate their intake and use them when needed. Animals overuse blocks where there is a chronic shortage of food, where the supply of blocks is interrupted or where the blocks are particularly 'attractive'. Reintroduction of blocks after a period without blocks often leads to a short period of over consumption. The major problem with over consumption is one of cost, although in some instances ill–health from high urea intake may occur.

On dry, low digestibility forages molasses/urea blocks are the minimum inputs needed to ensure maintenance of body weight. Where reproductive rates in cattle are low, these will generally return to reasonable levels. Blocks are often used in the remotest paddocks and they are an insurance against low calving rates. There is also strong evidence that the small enhancement of protein nutrition from the feeding of a molasses urea block to females may be sufficient to ensure an adequate milk supply for the survival of their new–born livestock or in the offsprings' first few weeks of life. On poor quality forages, birthweight of lambs and calves is low but can be increased to 'normal' with supplementation which achieves an optimum rumen digestive system.

The skill in using blocks lies in the ability of the manager to ensure adequate and continuous intake by ruminants over prolonged periods in both intensive and extensive grazing systems.

Molasses urea blocks which raise the P/E ratio in the animal augment the value of bypass protein by minimising the quantities needed. Molasses (which is a good source of trace minerals, and macrominerals, sulphur and potassium) when mixed with urea and other minerals (*e.g.* calcium and phosphorus) will generally maintain animals on dry forages. Whether to supplement further with bypass protein requires a decision on the target weight which, for example, might be a minimum weaning weight.

The Major Effect on Ruminants of Supplements to Low Protein Feeds

The overall effects of supplements to balance rumen function and metabolic efficiency are summarised below and are reviewed by Leng (1986) in his book *'Drought Feeding Strategies'*.

The key roles of urea (to supply fermentable–N) and of bypass protein meal (which supplies amino acids directly to the animal) in promoting productivity of ruminants fed on low digestibility forages are:

- Urea increases the efficiency of fermentative digestion in the rumen, stimulating feed digestibility and intake;
- Urea through its effects on fermentative digestion augments the nutrients to the required balance to allow the birth of a viable calf or lamb;

- Supplementation with a protein meal that largely bypasses rumen fermentation provides a better balance of nutrients to the animal, increases live weight gain and/or milk yields, and increases efficiency of feed utilisation in young animals, pregnant ruminants and lactating animals;

- Supplements of molasses/urea blocks with or without protein meals to mature cows, with calves at foot and grazing dry mature pasture, increases conception rate where these are below normal and, by implication, decreases intercalving interval. In young animals, age at puberty is decreased by strategic supplementation with a protein meal during the dry season;

- Cattle that are subjected to periods of low protein intakes during their early life may be stunted permanently so that their mature weight is often 100kg less than that of animals receiving bypass protein during these periods; and

- With sheep, similar generalisations can be made. In addition, it can be expected that bypass protein supplements will ameliorate the problems of low tensile wool strength and increase daily clean wool growth by about 1g clean wool per 100g cottonseed meal provided. Use of blocks will assist sheep to maintain their liveweight rather than to increase it; at the same time the animals maintain their reproductive efficiency.

The management options for using these supplements are many and varied and in the following discussion some strategies are reviewed. The economics depend on the situation, particularly the objectives of the animal production enterprise but often the ability to use supplements opens up options for setting targets to minimise the economic effects of a drought.

Graziers ought to set targets for their herd or flock at the onset of a drought. These usually include:

- A high reproductive rate;

- An opportunity to sell on a future market—for example, for feedlot entry or fat markets; and

- A condition that ensures rapid recovery from the drought when the weather breaks.

Target Live Weights

In a drought, herd size is normally reduced by strategic culling of unproductive animals. Where, however, after careful consideration, the property's drought strategy is to feed and maintain the nucleus herd, it is important that the feeding strategy aims at maximising reproduction and optimising calf survival.

It is mostly true that a drought feeding system aimed at growing animals is only potentially economic when a marketable product is delivered at an appropriate time. However, where a poor reproduction performance in the herd would occur if nothing is done, supplementation to achieve a 'normal' calving rate is likely to be highly economic.

High reproductive efficiency is the most important target of a drought management strategy. This usually means having cattle and sheep at a minimum weight and with a minimum condition just prior to the breeding season.

The most important guide to potential reproductive performance is knowledge of the average liveweight and liveweight change in a herd. The most important aids are, therefore, yards and animal scales. If scales are unavailable then the tape measure for predicting liveweight should be used.

Target—Mating Weight

Where the economic goal in drought feeding is to maximise pregnancy rates, graziers have to be mindful of the target weights essential for mating. This is because the onset of oestrus and successful pregnancy is related to mating weight and this weight varies according to the age, breed, lactational state and body fat stores of the female. A summary of the weights at which pregnancy can be attained may be seen in Table 1.

Lactation imposes a constraint to reproduction in breeding stock possibly associated with the suckling stimulus but also probably because of the drain of nutrients into milk, reducing availability of key nutrients to the reproductive organs. Cows should be 50–60 kg heavier than non–lactating heifers in order to overcome the lactational anoestrus *(see later)*. This is particularly so for 'milking' breeds including Simmental, Friesian x beef cross and Brahman crosses.

Aiming for a Market Weight of Livestock in Drought

Options in drought include the sale of animals and destocking. However, these options are only wisely taken when there is an ability to sell into a value added market. For example:

- Where animals are forward sold into a feedlot;

- Where a market on a particular date is predicted to be particularly well priced—for example coming out of winter into a wet spring when prices for finished stock may be high; and

- Where a decision has been made that, in the absence of drought relieving rains, the stock must be sold—finished stock under these circumstances

Table 1 Some recorded data relating breed type, liveweight and pregnancy rate in cattle.

Liveweight (kg)	Pregnancy rate (%)	Breed type	Ref:
Heifers (18-20 months)			
185	25	Shorthorn x Devon	Sparke and Lamond 1968
230	50	Shorthorn x Devon	
300	80	Shorthorn x Devon	
280	100	Hereford	Sawyer *et al.* 1991a
415	100	Simmental	Sawyer *et al.* 1991a
275	50-100	*B. indicus* cross	Doogan *et al.* 1991a
320	70-100	*B. indicus* cross	Goddard *et al.* 1991
Lactating 1st calf cows (26-30 months)			
300	67	Shorthorn x Devon	Sparke and Lamond 1968
365	100	Hereford	Sawyer *et al.* 1991a
465	100	Simmental	Sawyer *et al.* 1991b

will have a premium over non–finished or store stock, although prices may be reduced if large numbers of stock come on to the market suddenly (see *The Drought Survival Guide*, NSW Agriculture, p. 45).

Thus, whilst being able to adjust weight gain of breeding stock for high reproductive capacity is important, it is crucial to be able similarly to manipulate store stock liveweights. Improving the liveweight of cull cows is often overlooked, but they are also a major source of income on all properties and dry cows respond well to supplements.

Hitting Target Weights

There are a number of research studies that can be drawn upon as guidelines for farmers—to help them to 'hit' target weights. These depend on animal response rather than pasture availability and its analysis. We propose here a new approach to feeding management.

Models of the responses in liveweight of cattle on poor quality forages supplemented with either bypass protein (cottonseed meal) or 'energy' (grain) have been developed. These will enable the grazier to predict the likely shape of the response curve to supplements under conditions on their property.

The responses of cattle to minerals, to non–protein nitrogen and to bypass protein are well exemplified by data from around the world. Both solvent extracted cottonseed meal and expeller cake appears to contain around 75% of its protein in a form that is protected from rumen degradation (Leng *et al.* 1984). When fed to ruminants it therefore increases the amount of amino acids absorbed by the animal *per se*.

The responses in growth rate of young cattle to incremental increases in cottonseed meal or cake are shown in Figure 1 for eight studies from different areas of Australia and from other countries. The response relationships have been fitted to an equation as follows:

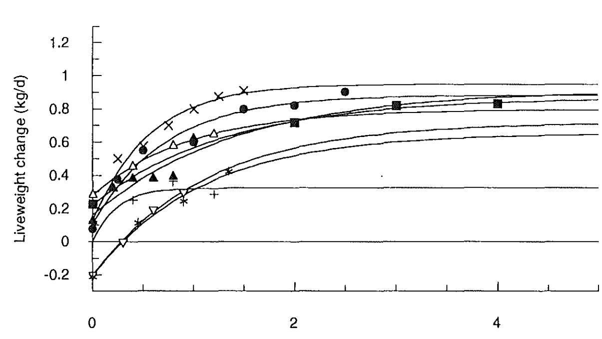
$$DGR = x + y\,(1-e^{-zq}) \qquad (1)$$

where Δ GR = growth rate in kg/d; x is growth rate without cottonseed meal supplementation; y is the potential growth rate on such a diet and z is the fractional growth response to cottonseed meal supplement level (q).

Whilst the shape of the response relationships between experiments is similar, the potential growth rate without supplements and that at optimum protein supplementation rate are often different between

Figure 1 Results from 8 studies of the effect of supplementing cottonseed meal or cake to cattle (140-200kg LWt) fed poor quality forages. Basal forages including straw, ammoniated straw and pasture.

- ● From Dolberg and Finlayson 1995
- x McLennan *et al.* (1994)
- ■ Dolberg and Finlayson 1995
- \+ Perdok and Leng (1990)
- D Perdok and Leng (1990)
- S Smith and Warren (1986a)
- Ñ Smith and Warren (1986b)
- S Elliot and O'Donovan (1971)



forages of different digestibilities. For example there is a large difference in growth rate of cattle fed straw or the same straw treated with ammonia to improve its digestibility. Thus, digestibility of the forage is an important factor determining feed value and determines the growth rate when only the rumen is balanced to support efficient microbial growth or when both the rumen microbes and the animal are balanced for nutrients.

Improving Survival of Young Animals

The second economic goal of drought feeding is to maximise the survival of newborn young weaners and breeding stock.

Lamb and calf survival are dependent upon:

1 Initial liveweight at birth (reserves of energy);
2 Weather conditions at birth;
3 Mothering ability of dam; and
4 Milk production of dam.

Where inclement weather conditions occur the birth weight and the energy resources available to the new born animal are critical to its survival; in general bigger is better: large new born animals have greater reserves of nutrients that can be mobilised to ensure survival over the first few days. However, survival is diminished where size results in dystocia.

The size of foetus is lowered by imbalanced forage diets; supplementation to ensure an active and efficient rumen appears to be sufficient to ensure the new born is of normal size (Table 2). Minimum supplementation for survival is therefore a mixture of nutrients aimed at optimising rumen function—for example, a molasses urea multinutrient block.

Table 2 The effect of supplying urea and sulphur to pregnant cattle and sheep given low N, low digestibility mature native pasture (NP) hay (Lindsay and Loxton, 1981; Stephenson *et al.*. 1981).

Species	Diet	Birth (kg) Weight
Cattle	NP hay	22
Cattle	NP hay + urea/sulphur	31
Sheep	NP hay	2.9
Sheep	NP + urea/sulphur	3.2

Predicting responses to a bypass protein

An average of the 8 results in Figure 1 provides us with a curve which can guide farmers in the use of supplements in field situations. This is shown in Figure 2.

To use the data shown in Figure 2 to predict the effects of supplementation, it is necessary to know the liveweight change of cattle on the pasture available to them when they are without supplements or receiving only molasses urea blocks. Once this initial growth rate is known, the shape of the response curve is presumed to be the same, but adjusted up or down for the initial quality of the pasture. Thus, if the growth rate was zero without supplements to achieve an initial growth rate of 200g/d, to meet a target weight increase in 100 days of 20kg would require 0.2kg/day of cotton seed meal fed to each steer each day.

A Comparison of the Nutritional Value of a Concentrate Mixture and Cottonseed Meal

Figure 3 predicts animal response in the field to a supplement. Here, the growth response in cattle given a 16% crude protein concentrate is shown for a straw silage when the digestibility has been altered by urea treatment. The response to supplementation on the treated straw (higher digestibility) was higher than that on the untreated straw up to the maximum fed (6kg).

Taking growth rates at zero supplementation (Figure 3) the theoretical growth response of cattle given straw plus increasing increments of cottonseed meal were fitted using the same equation used to generate Figures 1 and 2 but adjusted to the same initial liveweight change for straw alone. The two sets of data give clearly dissimilar response relationships (Figure 4). In Figure 4, the response to the cottonseed meal is greater than for the grain-based supplement up to 6kg on the treated straw but is only greater up to 2.5kg when fed to cattle on the untreated straw.

The predicted pattern of responses to supplements of cottonseed meal fed to cattle on a straw diet are completely different to that of more conventional concentrates, presumably because the cottonseed meal improves efficiency of feed utilisation and a grain based concentrate progressively substitutes for the basal diet.

Using the Information to Set Supplement Rations

Using this approach, then, it is possible to predict the growth from measurement of the growth rate without supplementation. The curve is then made to fit through the initial growth rate and the level of supplementation can be calculated to achieve a weight gain necessary to meet a target liveweight.

If the initial liveweight gain without supplements indicates that even with the optimum cottonseed meal supplement the targeted growth rate cannot be achieved, then the basal resource (mostly pasture) must be progressively replaced with higher quality feed (such as lucerne hay) until a response curve starting at the higher initial growth rate enables a sufficiently high growth rate to be achieved—or a decision made to abandon feeding and sell.

Predicting Growth Response to Supplementation and Other Protein Meal on the Farm

A major problem for all graziers is that cottonseed meal increases in price dramatically in drought with increasing demand. The high prices have led commercial enterprise to develop protected protein meals in which formaldehyde is used to protect proteins in meals. In Europe and the USA a simple sugar, xylose (1%), is used with mild heat to protect soyabean protein meal. Small amounts of molasses mixed into the protein may result in similar protection through the reaction of the protein with simple sugars in the molasses under mild heat. The availability of a number of protected protein meals has provided the necessary market competition to keep prices of such meals reasonable. Recently, copra meal has been imported from the Pacific region and it is claimed to have a well protected protein content. However, this estimate was based on an experiment undertaken at Grafton by Hennessy *et al.* (1990) using a single source of copra meal which had been pelleted under high pressure. Caution should be adopted when using this value for copra meal which now is sold unpelleted. It is up to the importers of this meal to demonstrate the effectiveness of each batch of meal as a bypass protein source. The grazier should certainly assess the meal as it is supplied to them with on–farm research.

Any protein meal that is sold and claimed to have bypass protein content should be certified by animal experimentation. All that is needed is two groups of

Figure 2 Composite curve developed from the responses of cattle fed low quality forage and levels of cottonseed meal (the data are the average of the fitted equations shown in Figure 1. The composite curve has the equation.

$$\Delta GR = 0.069+0.679(1-e^{-1.12q}) \quad (1)$$

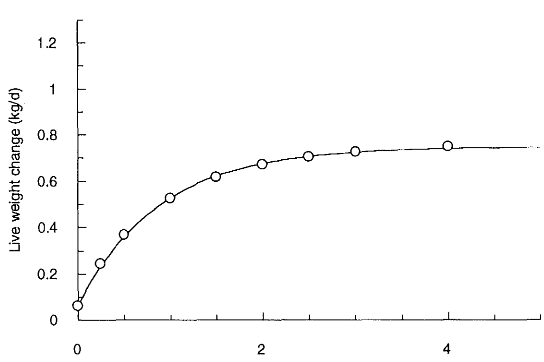


Figure 3 Growth response to cattle fed wheat straw or urea ensiled straw where digestibility has been increased by up to 10 units and supplemented with a 16% crude protein concentrate (Creek *et al.* 1983). Growth rate at zero concentrate intake was predicted.

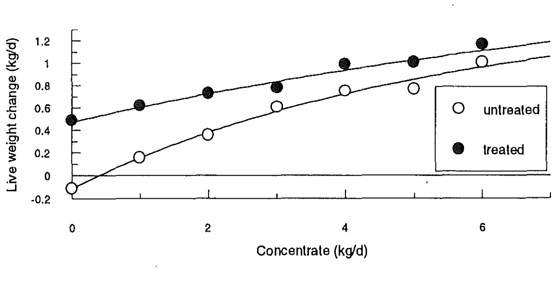
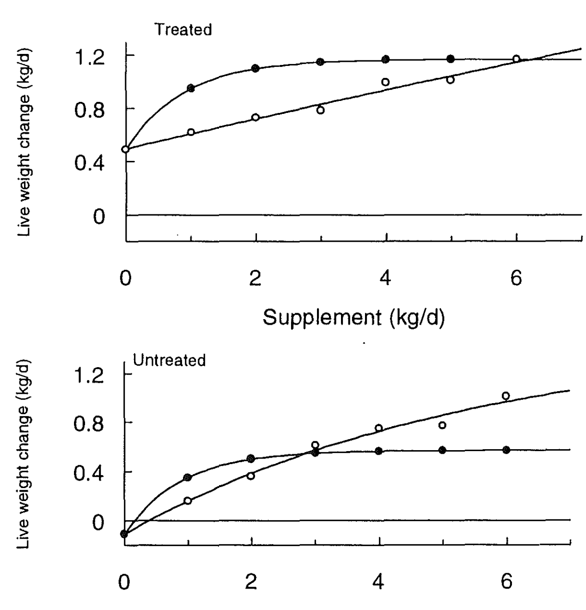


Figure 4 The relationship of growth rate and supplement intake (concentrate (o); cottonseed meal (·)) of cattle fed untreated straw and straw treated with ammonia to improve digestibility. It is clear that the cattle substituted concentrate for straw, whereas a bypass protein in this case tends to maintain or increase intake of the basal forage (see Leng, 1990).



steers, one fed with copra meal preferably with a molasses urea block and the other fed only the block. A 50 day feeding trial would be sufficient time to assess the effectiveness of copra meal. There must be some doubt about the bypass protein quality of the presently imported copra meals until the necessary research has been undertaken.

Economic Evaluation of Supplementation in Drought

There are no reported response curves for different genotypes fed low quality forages and supplemented according to the recommendation made here. This highlights the dilemma of the farmer and the lack of servicing that he receives from nutritional research. There are no standards prescribed for bypass protein meals and different products, even from similar sources, differ greatly in their content of bypass protein depending on how they are processed. During the 1995 drought it was difficult to recommend rates of supplementation based on unknown protein sources such as copra meal.

The most comprehensive study where genotypes have been compared in terms of their responses to bypass proteins is from NSW Agriculture in Grafton. These results are shown below and emphasise the lack of knowledge in the particular area.

Grafton Studies on Responses to Bypass Protein of Cattle on Dry Native Pasture

Maiden heifers, 20–25 months of age, were purchased in April 1990 and allocated to experimental sites on Grafton Agricultural Research Station and on sites leased from graziers within the district. The sites were subtropical unimproved pastures.

The genotypes chosen were:

- Hereford;
- Brahman x Hereford, F_1; and
- Brahman.

The animals grazed low quality pastures during the drought years 1990–93 and were supplemented for 130 days from each July with cottonseed meal at the following rates:

- Nil supplement;
- 750g/day equivalent, given twice weekly; and
- 1500g/day equivalent, given twice weekly.

The rainfall received during the study period is indicated in Figure 5 and, for most months, was below that expected. With the exception of the period December 1991 to February 1992, the whole of the district was 'Drought Declared'.

Mating Weight

During the first year of mating (1990) the liveweight response to supplementation could be estimated from Equation (1) and compared with the composite line as shown in Figure 2, since liveweight changes were not confounded with those due to pregnancy or lactation. Table 3 shows the heifers from the different genotypes responding differently to CSM, with the Herefords responding as predicted and, at the other end of the spectrum, no response at all by the F_1 heifers to the CSM.

From the 1990 pre–mating growth rates, according to Table 3, we could have removed the Brahman F_1 from the study and directed our efforts at improving the reproductive efficiency of the Hereford and Brahman cows, and the quality of their weaners; however, we needed to assess the effectiveness of CSM for maintaining lactation and fertility through a prolonged drought for all breed types. The mating weights adjusted for the effects of years during the study (Figure 6) show a highly significant improvement in the mean mating weight (at October) for Herefords (a 70kg increase) and an improvement for Brahmans (a 44kg increase) with a smaller effect (33kg) on the F_1 cows, as predicted.

Calving Rate

The calving rate was increased by supplementation when 3 years' results were included in the data analysis. However, there was a significant breed type x supplementation interaction. Brahman x Hereford cows had increased rates with 750g CSM/day and Hereford cows when supplemented with 1500g/day. Brahman cows had a mean rate of $55 \pm 17.7\%$ and the rate did not increase with supplementation (Table 4).

Growth and Survival

In December 1991, the first–draft of calves were early–weaned (110 days of age) in order to prevent cow deaths and to hasten a return to oestrus. The calves were sold. Over all years, the growth rate of Hereford–suckled calves from their supplemented dams was higher than the rate for those being suckled by non-supplemented dams (640 *v.* 500g/day). There was no difference in other genotypes between supplemented and non–supplemented growth rates. Weaning weight, which represents age-to-weaning and growth rate, was increased by supplementation (Table 5), with the greatest benefit being to those calves suckled by supplemented Hereford cows.

Financial Returns

The benefit of supplementation in a beef breeding enterprise is dependent on the price for both the weaner and the cull cow. Each weaner, irrespective of

Figure 5 Rainfall recorded on sites during the drought period 1990–93 at Grafton, N.S.W.

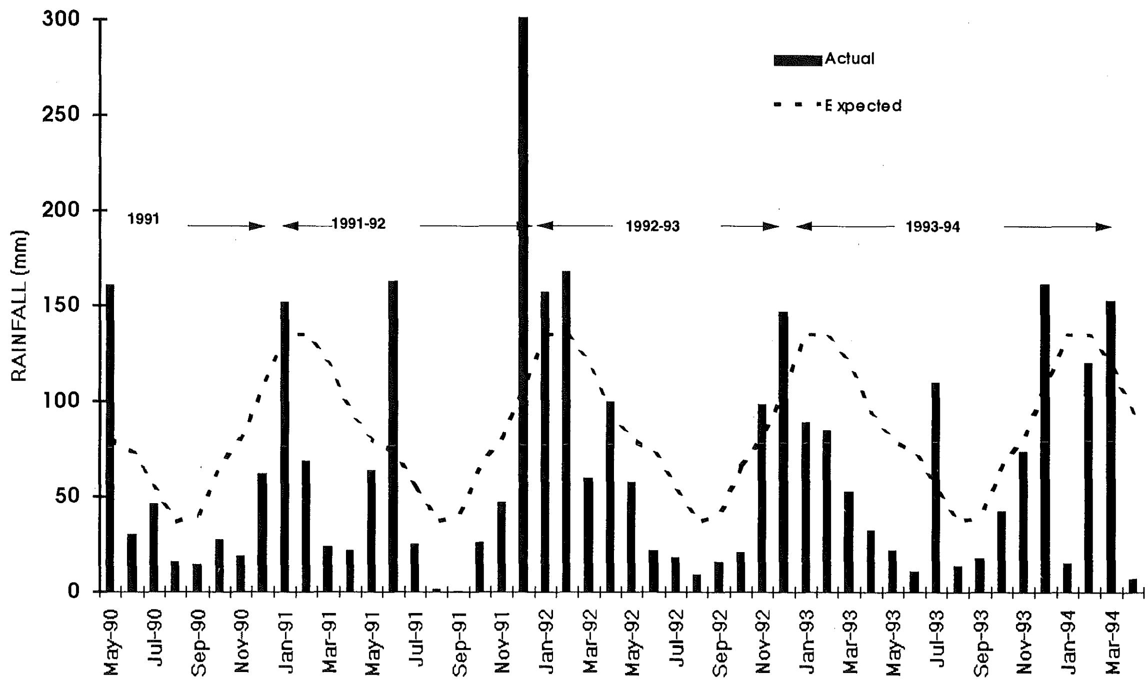


Table 3 Predicted potential growth rate (y), fractional growth rate (z) and non-supplemented growth rate (x) (g/day) of heifers during CSM supplementation, pre-mating, 1990. See also Equation (1).

Breed type	Predicted growth rate	Fractional growth rate	Non-supplemented growth rate	Significance
Hereford	477	1963	-127	**
Brahman, F_1	-5	0	8	NS
Brahman	472	43	58	*

genotype or treatment origin has been assigned $1.65/kg liveweight (Davies and Llewellyn 1994) and the cull cows $0.85/kg. Cottonseed meal was priced at $325/t. In these budgets the extra returns were compared to the extra costs. However, as a drought strategy where the cattle would have to be fed, the costs of labour, feeding equipment and storage of $7.30 per cow per year for those offered 750g/day and $9.30 for those offered 1500g/day have not been included. The economic response to feeding 1500g/day was compared to nil, and to 750g/day. The response of feeding 750 was compared to nil (Table 6). The budget indicates that for Hereford cows, the negative returns at 750g/day argue against feeding at this rate but at 0 *v.* 1500g/day, the marginal rate of return is 51%—highly profitable. The measure of success is to compare the marginal rate with the rate of borrowing money required for the investment. This latter rate is currently 9.5%.

According to Cimmyt (1988), the required rate of return ought to be double the cost of capital to make it worthwhile for farmers to implement the enterprise; hence the target rate should be 20%. Therefore, using set livestock prices and for feeding CSM for 130 days it should be a recommendation to supplement Hereford cows to 1500g/day when grazing low quality pastures typical of the early stages of a drought. For the crossbred cows, using a similar feeding regimen feeding should perhaps be less than 1500g/day. On the other hand, for the pastoral conditions experienced it was not profitable to supplement Brahman cows at any rate, hence the supplementary regime used in the study is not recommended for this breed type.

Protein Meal Availability

There is a problem with supply and price of meals during a drought as there is often with the supply of roughages and even cereal grains. During the period May 1992 to August 1994 soyabean meal was somewhat exceptional in that it was readily available) at a maximum price range of $440-530/tonne bagged. Overall, cottonseed meal, the recommended meal, had a 'fair' availability, although availability was only from fair to scarce in most of 1993. The maximum price range of cottonseed meal was from $290-450/tonne bagged (Sydney Retail Feed Ingredient Price, NSW Agriculture, Windsor; Survey, May 1992 to August 1994). The availability of canola meal, sunflower meal and meatmeal was similar to c cottonseed meal during the drought. But graziers must be aware that these meals are internationally–traded commodities and factors external to Australia affect their supply and price. It may be a better management option to have forward contracts with major suppliers as part of a regular feeding routine than to rely on spot purchases of meals purely as a drought strategy.

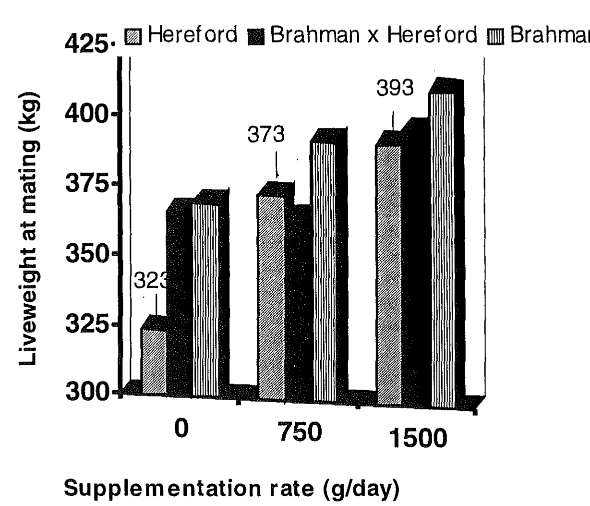
Table 4 Mean calving rate (%) over 3 years for cows of 3 breed types supplemented with CSM.

	Rate of supplementation (g/day)		
Breed types	0	750	1500
Hereford	75	75	89
Brahman x Hereford	69	83	89
Brahman	53	56	56

Table 5 Weaning weights of calves from each genotype.

	Rate of supplementation (g/day)		
Breed types	0	750	1500
Hereford	132	148	184
Brahman x Hereford	158	175	180
Brahman	128	171	153

Figure 6 Mating weights (at October) of three breed types increased by CSM supplementation over 3 years and adjusted for the effects of years.



Protein Meal Storage

When graziers decide to feed large quantities of protein meals they need to have facilities for downloading and easy access to bulk delivered meals. Meals do not flow well and do not store well over long periods (*e.g.* > 6 months) due to moisture and development of fungal growth. Hence, for smaller users (*i.e.* < 20 tonnes) storage in bags under dry conditons is preferred with rodent control necessary. Pelleted meals are a better option for storage and are easier to handle and feed out.

Protein Meal Handling

When feeding out to stock it is important to have sufficient trough space (300–600mm/ cow) to allow shy feeders access. Feeding twice a week also allows most stock to consume their allocation and reduces the labour costs of feeding out compared with daily feeding. Cottonseed meal has a high acceptability to at least cattle, but other meals (*e.g.* meatmeal) may be less acceptable and the use of sweeteners (such as molasses) or experienced stock may help adjustment to the less acceptable meals. Pelleting, although adding to the cost, can reduce losses in feeding out and negate the need for supplying troughs. Pelleted meals can be placed in small heaps on the ground.

Conclusion

British Breed Cattle

These have a high requirement for additional N and protein when dry standing forage of a subtropical or similar pasture is available. For maiden heifers, graziers can predict the amount of CSM (or a similar quality product) required as a supplement for them to reach a target mating weight, or a marketable cull cow weight. The partial budgets showed that, during the 3 dry

Table 6 Partial budgets and investment analysis of feeding 750 or 1500 g/day of cottonseed meal.

	Comparison of feeding level		
Per 100 Cows	750 v. 0	1500 v. 750	1500 v. 0
Hereford			
Extra calves (no.)	0	14	14
Extra total LW (kg)	648	5248	5896
Extra income ($)			
weaners	1069	8659	9728
cull cows	264	228	492
Extra costs ($)	3209	3545	6753
Net returns ($)	-1876	5342	3467
Marginal rate return (%)	-58	152	51
Brahman x Hereford			
Extra calves (no.)	14	6	20
Extra total LW (kg)	3874	2096	5970
Extra income ($)			
weaners	6392	3458	9581
cows	264	228	492
Extra costs ($)	3651	3205	6857
Net returns ($)	3005	481	3216
Marginal rate return (%)	82	15	47
Brahman			
Extra calves (no.)	3	0	3
Extra total LW (kg)	880	-1113	-233
Extra income ($)			
weaners	1452	-1837	-385
cows	264	228	492
Extra costs ($)	3273	2895	6168
Net returns ($)	-1557	-4504	-6061
Marginal rate return (%)	-48	-155	-98

years, a minimum of 1500g/day of CSM should be fed to British–breed cows to initiate cycling and enhance fertility, and to maintain growth rates of suckled calves above 600g/day. These achievements occur presumably because the priorities for supplementary feeding are met. These enhance the rumen ecosystem for maximum digestibility and optimum microbial growth and therefore P/E ratios. When these priorities are met, the basal diet of forage and cottonseed meal supports surprisingly high levels of production. However, these results were obtained on subtropical pastures with a protein meal with a well recognised 'protection' level. Responses to other meals, such as copra and formaldehyde–treated sunflower meals are less well known and the relationship between quantity fed and improved production has to be established to determine the economic rates of feeding during droughts. Also, with highly protected protein meals, it seems that a source of non-protein nitrogen will be additive in its effect on production and therefore the use of multinutrient blocks is recommended. In many situations where cottonseed or other protein sources are fed at below optimum responses then multinutrient sources such as blocks will effectively increase production.

Crossbreds and Bos Indicus Breeds

There was no apparent liveweight response in the first year by F_1 heifers to supplementation but the effects of lactation obviously increased the nutrient demand above that sustainable from the native carryover pastures and the cows responded to supplementation with time. The Brahman x Hereford first cross breed type is recognised from previous studies as having a high production capability even on sparse low N pastures, but supplementation is required to maintain production during lactation. Hence, graziers with this genotype, when dry pasture is available, should supplement between 750–1500g/day during the critical lactation–early mating phase to maximise their economic returns.

There was no economic response to supplementation for the Brahman cows. However, on pastures where dry matter availability was higher this breed type responded to CSM supplementation. The differences in genotypes and their response to supplements require to be worked out before a generalised recommendation can be made for all animals on supplements during drought. Where there is still a carryover of dried pasture, Brahman cows should be supplemented with high rates of CSM (minimum of 1500g/day) for a short period (from 50–90 days), commencing before calving (Fordyce and Entwistle 1992) and if the drought persists, early weaning of calves (at 80+kg) is required to break anoestrus and allow an opportunity for cows to conceive in the next season. Again, as for the other genotypes, the response to other meals and to molasses urea blocks in cooler environments is not well established and needs to be so for reliable guidance to graziers in all of the drought-susceptible areas.

The low response of first cross and Brahman cows to supplements in the studies at Grafton should be seen in context, as responses in overseas research with Brahman cattle fed straw have been similar to British breeds fed straw. There is therefore some intrinsic differences which may be associated with local environments or the nature of feed resources. This points to a need for widely developed regional data on the responses of cattle to feeding a standardised protein meal. It also indicates a danger in not testing different sources of protein meals for their abilities to promote production in cattle on dry pastures.

It is a recommendation for consideration of the panel that the establishment of response relationships to supplements regionally to provide examples for graziers would be a better approach to guide supplementation strategies in future droughts rather than an approach which depends on laboratory analysis of 'feed quality'.

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Cereal Grains and Energy Supplements for Drought Feeding

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Summary

Cereal grains offer a cost effective source of supplementary feed for maintenance or production but their use is often limited by the difficulty and danger of feeding them to grazing sheep and cattle. While cereal grain is more expensive and not as readily available when most needed in severe droughts, it still tends to be more accessible and cheaper than other supplements such as protein meals and legume grains. Protein supplements provide similar, or even better responses than cereal grains without the dangers associated with cereals. Because of the safety of feeding protein supplements and the perceived benefits of additional protein these supplements are also consistently and significantly more expensive than cereal grains.

Comparisons between cereal grains and protein supplements are not easy to make because the difference between these two types of supplements includes the presence or absence of starch as well as the amount of protein which they supply. The presence of starch can have a negative effect on the animal through rapid fermentation in the gut which leads to reduced fibre digestion and the accumulation of acid which can cause low gut pH and acidosis. The compound virginiamycin (sold as Eskalin™) reduces the risk of acidosis and overcomes many of the adverse side effects of feeding grain. The use of virginiamycin to make it safer to feed cereal grain provides more flexibility in the choice of supplement. Once the adverse effects of starch are overcome, using virginiamycin, cereal grain can be just as good a supplement as more expensive protein supplements in most situations. The use of grains with virginiamycin as components of balanced supplements in conjunction with non-protein-nitrogen, true protein and minerals requires more work, but is theoretically the most flexible and cost effective option available for feeding cattle when the nutritive value of paddock feed is limiting.

Production feeding even in times of drought offers many advantages compared with feeding for maintenance and survival. Feeding grain rather than hay or other low quality roughage provides the opportunity to finish cattle and sell them at a premium price. This option maintains cash flow at a difficult time by feeding to convert almost unsaleable cattle in store condition to marketable finished cattle. A second benefit is that selling cattle also reduces the overall grazing/stocking pressure. On the other hand, feeding for maintenance or survival in a drought is a risky option which can only be justified when sheep are being managed to produce a quality fleece, when valuable female animals are being managed to maintain reproductive efficiency and when young animals are being supplemented for survival. Even in these situations selling and repurchase is often more cost effective.

It is far easier to buy, store and sell grain than is the case with hay or silage. Cheaper feed grain or weather–damaged grain is almost always available around harvest time but livestock producers do not often have the infrastructure to take advantage of this fact. Purchase and storage of grain requires some capital infrastructure in the form of silos, augers *etc.* and the availability of cash for purchasing a commodity at a time of the year when it is often not seen as an essential requirement. It also requires some technical expertise and experience in storing the grain and maintaining it free of insects without creating any pesticide residue problem when the grain is fed out. While there are a number of mixed farms producing both grain and livestock there are a far larger number of producers who specialise in either cropping or livestock production. In the case of specialist producers there is considerable scope for developing strategic alliances between grain growers and livestock producers in order to spread the risks and benefits of commodity price changes across grain, beef and wool. Once the grain is on hand it can be fed through sheep or cattle or sold for alternative uses if this option brings a greater return. In order to retain this flexibility the grain needs to be stored well and must be easy to handle. Livestock producers and grain traders can also develop arrangements based on forward contracting as is currently possible in the case of molasses.

The nutritional value of cereal grains can be enhanced considerably by addition of non–protein nitrogen (urea), minerals such as calcium and small amounts of protein in some situations. It is also cost–effective to process cereal grains before feeding them to cattle. The cost of processing is considerably reduced by economies of scale and the use of appropriate equipment. When considered together with the logistics of buying and storing grain there are some important benefits which emerge in favour of larger scale centralised grain handling and processing facilities. This opens up the possibility of providing a complete feed service industry whereby feed, feeders and the job of feeding out are all covered in a single price as $/day to achieve a set objective or $/kg liveweight gain. While there is a developing industry in protein meals this has not yet extended into feeding systems based on cereal grains. As we understand how to use cereal grains more safely and effectively there is increasing scope to develop more flexible and cost–effective feeding systems for production and survival of livestock during drought.

Introduction

Our first priority in sheep and cattle production systems must be to do everything possible to maximise the sustainable use of pastures and forage shrubs. However, it is a fact that the quality and availability of pasture varies dramatically within and between years. Against this variation in the pasture–based feed resource there is increasing market demand for quality and continuity of supply. Prices paid for meat and fibre increasingly reflect our ability to meet the market requirements. In turn good prices and profitable production enhance our ability to manage pastures and rangeland in a sustainable way. Effective drought management practices must therefore focus on the objectives of continuing to produce a saleable product while preserving the productive capacity of the pasture. The strategic use of grain supplements offers a potential tool by which to achieve these objectives.

Biology and Efficacy

In most parts of Australia cereal grains are a cheaper source of digestible energy than hay or silage. This is particularly true if these forages need to be transported from other regions as occurs in times of drought. Grain is also easier to store and handle than forages and this provides the opportunity to buy and sell grain as requirements and prices change with the season. A further advantage of grains is that they provide the potential for increased growth rate or higher levels of production than are achievable using low–quality roughages and conserved forages.

The usefulness of cereal grains for herbivore feeding is, however, restricted by problems associated with the rapid fermentation of starch and the risk that this may lead to acidosis. The consequences of acidosis for animal health and production may be serious. The common effects are a reduction in feed intake, lower growth rates, low tensile strength in wool and, in serious cases, death can result. The problems associated with acidosis are widely recognised and have a profound impact on the selection of grain type, and the methods by which it is fed. These risks have been enough to discourage many producers against using grain in sheep and cattle production systems unless it has been absolutely essential, as in the case of drought. Even during drought relatively few producers will use grains such as wheat because of the perceived danger. Over the last decade prices paid for lupin and whole cotton seed have increased to the point where they are significantly more expensive than cereal grains. This has largely been justified on the basis that they have higher protein. In this paper we suggest that the main advantage in the 'protein' grains is primarily because they contain very little starch which makes their use safe and effective. Once the problems of acidosis are overcome then cereal grains can, theoretically, be considered together with the protein grains in terms of their strategic use to manage variation in pasture feed across seasons and between years.

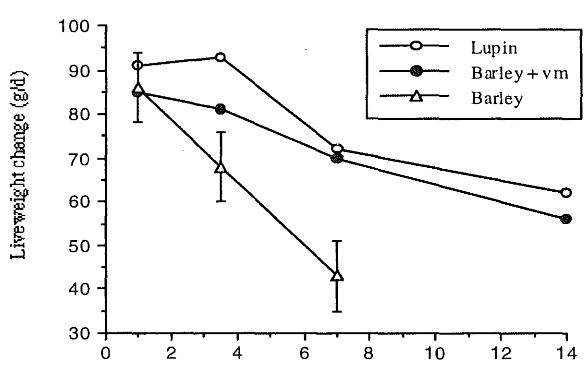
The nutritive value of cereal grains and 'protein supplements'

All feeds contain some protein and some digestible energy and there is no clear distinction between 'protein' and 'energy' supplements. There is a widespread belief that protein is always the most important nutrient to consider when formulating diets and supplements for grazing animals. This is not necessarily the case. The most important factor in any program of supplementary feeding for ruminants is to ensure a balanced diet and provide conditions where the microbes in the digestive tract can break down fibre and produce protein in the most efficient way. If conditions are good for the microbes to produce protein efficiently they have the potential to produce sufficient protein for practically all classes of animals.

Numerous production trials have compared supplements based on cereal grain with those containing high levels of protein. Almost without exception the protein supplements have produced superior performance compared to those based on cereal grain and the conclusion has been drawn that the animal has a requirement for protein which the cereal grain cannot supply. This conclusion is, in most situations, incorrect. It is incorrect because the cereal grain supplements normally have an adverse effect on fermentation and digestion which has nothing to do with protein levels. This negative effect reduces the microbial protein synthesis and reduces the effectiveness of the bacteria breaking down fibre. These effects in turn reduce feed intake because the animal cannot digest fibre as effectively and cause an imbalance in nutrients available to the animal because there is a deficiency in protein. The adverse effects of acidity are often exacerbated because it is rare, under paddock conditions, to feed additional nitrogen with the cereal supplement and this creates an even greater shortage of nitrogen for the microbes as they attempt to produce protein during fermentation of the carbohydrate. This additional nitrogen for microbes to use in the production of protein can be provided very economically in the form of urea or ammonium sulphate and does not have to be provided as expensive protein. Provided that acidity is controlled and microbial substrates are available then microbial protein synthesis should meet the protein requirements of all classes of animals apart from young animals growing rapidly or female animals in late pregnancy and the early stages of lactation.

This difference between responses to cereal grain and protein supplements is illustrated well in the study reported by Godfrey *et al.* (1993b) in which cereal grain and lupins were fed to sheep daily, twice weekly, weekly or fortnightly. It shows that when the two grains were fed each day and there was no adverse effect of the starch on fermentation, and no benefit associated with the additional protein supplied by the lupin grain. When larger amounts of barley or lupins were fed at twice weekly or weekly intervals there were clear adverse effects in the case of barley due to the supply of large amounts of starch at irregular intervals. This was thought to be due to rapid fermentation of starch reducing pH and having a negative effect on fibre degradation and microbial protein synthesis. However, the use of virginiamycin to reduce the adverse of acidosis transforms barley into a supplement which is used ad effectively as lupins (*see Figure 1*). More detail on overcoming acidosis and the use of virginiamycin is provided in more detail later in this paper.

Figure 1 The effect of feeding barley or lupin grain daily, twice weekly, weekly or fortnightly at levels equivalent to 200g/d to animals with free access to hay containing 1.5% urea. The barley was fed with or without virginiamycin (Vm). The bars represent the standard error of the difference between treatments (s.e.d.). (Godfrey *et al.* 1993b)



Further evidence for the importance of microbial protein synthesis is provided through experiments measuring wool growth in grazing sheep fed supplements of either lupin or cereal grain (Rowe *et al.* 1989a). Under these conditions wool growth was directly related to the amount of grain fed irrespective of type of grain or amount of protein supplied. While it is known that the protein of lupin is extensively degraded in the rumen (Hume 1974) and also has low levels of methionine for wool growth (Murray *et al.* 1991), it is also clear that protein from microbial synthesis is an adequate source of amino acids for wool growth in sheep supplemented with cereal grain. Most responses in wool growth to specific protein supplements have been demonstrated in sheep housed in pens and fed semi–purified diets. Extrapolation of the results of these studies in penned sheep to predict responses to protein supplements in grazing sheep should be regarded with caution.

Hay, protein and cereal supplements—the effect on gut fill

The weight of digesta in the rumen can vary significantly in response to different supplements and can influence the weight of the animal. This is another factor which can lead to an incorrect interpretation of the value of cereal grain as opposed to hay and protein supplements such as lupins. When cereal grain such as barley is fed, the weight of the gut is reduced and the animal appears to lose weight. On the other hand when hay or chaff are fed the amount of material in the gut remains the same or increases and this makes the animal heavier. When judged on liveweight alone it appears that barley may be an inferior supplement but in terms of the nutrients supplied to the tissues and the weight of the carcase, cereals can be good supplements. The results summarised in Table 1 show sheep fed a supplement of barley appeared to lose 2kg liveweight over a three week period compared to sheep fed chaffed hay. However, this entire difference was explained by the difference in the weight of the gut contents and there was in fact no difference between the feeding treatments in terms of carcase weight.

Why are some cereal grains more dangerous than others?

The extent to which different cereal grains are used for feeding grazing ruminants reflects the relative risk of acidosis associated with these grains. The risk of acidosis is related to the amount of starch consumed and the rate at which it is fermented. Wheat is the most dangerous grain to feed and the reason for this is clearly seen in Table 2. It contains relatively high levels

Table 1 The effect of chaffed hay or barley on gut fill, liveweight and carcase weight 3 weeks after a change in diet. Sheep were offered either 1kg of chaff or 700g barley/d to provide approximately the same amount of digestible energy. (Rowe and Coss 1992)

	Chaff		Barley		P
	mean	s.e.	mean	s.e	
Initial liveweight (kg)	33.0	0.58	33.0	0.8	NS
Feed intake (g/d)	994	2.5	625	27.4	***
Liveweight change (kg/21d)	-0.19	0.28	-2.06	0.36	***
Carcase weight (kg)	13.4	0.32	13.6	0.41	NS
Reticulo rumen (kg)	5.13	0.26	3.17	0.29	**

Table 2 The fermentation and digestion of starch from different cereal grains by ruminants (from [1] Nocek and Taminga, 1991 and [2] Huntington, 1994). The data refers to grains hammer milled or dry rolled.

	Maize	Sorghum	Barley	Wheat	Oats
Starch content (% of DM)[1]	76	75	61	76	42
Digestibility					
Rumen (% of intake)[1]	76	64	87	89	92
Post rumen (% of duodenal flow)[2]	66	63	73	85	76
Whole tract (% of intake)[2]	93	87	93	98	98
Solubility (% loss from nylon bags)[1]	26	32	54	68	96
For each kg DM consumed					
Starch intake (g/d)	760	750	610	760	420
Starch fermented in rumen (g/d)	578	480	531	676	386
Starch digested post ruminally (g/d)	120	169	58	71	26
Starch excreted in faeces (g/d)	57	97	40	14	7

of starch which is extensively fermented in the rumen. Wheat starch is highly soluble and fermentation is therefore both extensive and also very rapid. On the other hand even though oats contains starch which is readily fermentable it has the lowest level of starch compared to wheat and barley. This low level of starch and the fibre provided by the hull of the oat grain (25 to 30% of the dry matter) makes it relatively safe to feed to ruminants and explains why it is the traditional grain for ruminant feeding. The use of lupin grain is widespread in Western Australia and is gaining popularity elsewhere in Australia. Although it is not a cereal grain it is interesting and relevant to discuss its success as it indicates the potential use of cereal grains if we can overcome the risk of acidosis. Lupin grain and cotton seed contains little or no starch and can be fed to sheep and cattle with complete safety. This safety means that it can be fed out, even without a gradual period of introduction, at weekly or fortnightly intervals with no risk of ill health and without reducing its effectiveness as a supplement (Rowe and Ferguson 1986, Morecombe *et al.* 1988).

Reducing the risk of acidosis

The use of lupins in experiments and under commercial conditions has provided a major breakthrough in demonstrating a range of benefits associated with feeding grain supplements to grazing animals. Lupins have some unique properties including the fact that they contain no starch. This makes them extremely safe to feed and makes them an effective and compatible supplement for use with a wide range of basal feeds. We believe that by understanding the reasons behind the nutritional benefits of lupins we can begin to modify the fermentation and digestion of starch in order to facilitate the safe and effective feeding of cereal grains. Once the problems of starch fermentation and acidosis are overcome it is possible that cereal grains may even have some advantages by supplying preformed glucose in the form of starch to ruminants.

The most common way of minimising the risk of lactic acidosis is the slow adaptation of animals to increasing levels of starch in the diet. This provides an opportunity for the microbes to adapt to the fermentation of the new substrate and for the animal to adapt its pattern of intake and digestion for the new feed. It is common to introduce increasing levels of grain over a period of around 2 to 3 weeks. During this period, it is the bacteria which convert lactic acid to acetic and propionic acid, which build up and stabilise *(see Figure 2)*.

Even with the gradual introduction of cereal grain some animals consume more than the desired amount of grain and problems of acidosis can still occur. With this continued risk of acidosis three types of additives have been used in attempts to reduce the adverse effects of rapid starch fermentation and/or problems with acidosis. These are: nutrients which facilitate balanced and efficient fermentation; buffers such as bicarbonate to maintain pH within physiological limits; and antibiotic feed additives which specifically target the bacteria which continue to produce lactic acid at low pH.

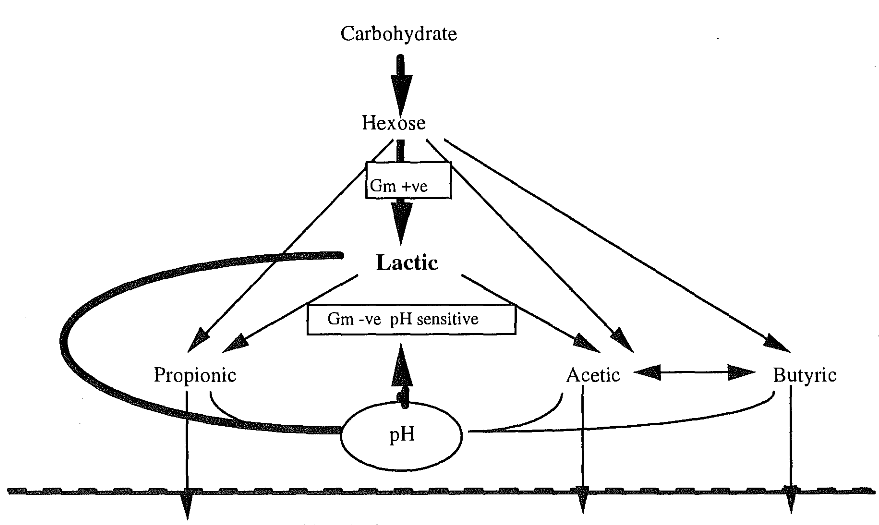
Nutrients which Facilitate Efficient Fermentation and Digestion of Starch

Urea and ammonium sulphate balance the supply of substrate for microbes during the rapid fermentation of starch in the rumen and improve the efficiency of microbial growth. It is likely that this helps organisms to adapt more rapidly to the sudden change in supply of carbohydrate. Sources of soluble protein in the diet can also provide the nitrogen required to balance the nutrients required for the rapid fermentation. Through efficient fermentation and microbial protein synthesis more carbon is incorporated into microbes and less is available for acid production. There is also evidence that protein may have a role in improving the efficiency of starch absorption from the small intestine which in turn decreases the risk of too much starch entering the hindgut (Taniguchi *et al.* 1992, 1993).

Buffers and Agents which Slow Down Fermentation of Starch

The most common buffer used is sodium bicarbonate. The effect of bicarbonate has been investigated in numerous metabolic studies and in various production trials. Xu *et al.* (1994) concluded that the addition of buffers to the diets of dairy cows occasionally increased milk fat percentage without any measurable effect on rumen pH or VFA concentration. Zinn and Borques (1993) similarly found no measurable effect of bicarbonate on rumen pH or on the site of starch digestion in feedlot steers. The use of bicarbonate has also been shown to be ineffective in reducing the proportion of animals with acidosis following administration of ground wheat into the rumen (Aitchison *et al.* 1987). It is therefore concluded that buffers such as bicarbonate offer little protection against acidosis when feeding rapidly fermentable carbohydrate to ruminants.

Figure 2 Major pathways associated with the fermentation of starch and the build up of lactic acid. With rapid fermentation there is a build up of acid in the rumen which has an adverse effect on the bacteria which convert lactic acid to acetic and propionic acid. The acidity does not have an adverse effect on the bacteria producing lactic acid. As lactic acid starts to accumulate it further reduces the pH since it is not absorbed from the rumen as rapidly as the volatile fatty acids (acetic, propionic and butyric).



Antibiotic Feed Additives to Control Lactic Acid Production

Nagaraja *et al.* (1981) demonstrated that the ionophores monensin and lasalocid were effective in reducing the accumulation of lactic acid in fistulated steers given high levels of starch. However, there does not appear to be evidence of ionophores being successfully used to facilitate the safe feeding of cereal grain under feeding systems where the risk of acidosis is likely to be high. Further work by Nagaraja *et al.* (1987) showed a wide range of antibiotic feed additives to be effective against lactic acid accumulation when incubating rumen fluid with glucose. These additives are all selectively active against Gram positive bacteria including *Streptococcus bovis* and *Lactobacillus sp.* which are known to be important in production of lactic acid from hexose *(see Figure 2)*. Further screening work in Western Australia identified virginiamycin as a most effective compound for controlling lactic acid accumulation under conditions *in vitro* as well as in sheep (Rowe *et al.* 1989b) and cattle (Thorniley *et al.* 1994). In addition to controlling lactic acid accumulation in the rumen in animals fed high levels of grain, studies by Godfrey *et al.* (1993a) showed the control of acidosis in the hindgut with virginiamycin. The use of virginiamycin has now been tested under conditions of pen feeding and in grazing animals fed supplements of cereal grain and there is comprehensive evidence that it reduces the risk of acidosis to the point where cereal grains can be fed in a similar way to lupins (Rowe and Zorrilla-Rios 1993). A good example is illustrated in Figure 1 which summarises the data of Godfrey *et al.* (1993b). This shows that even when 2.8kg of barley with was fed out at fortnightly intervals liveweight gain and feed intake are similar to when lupins are fed. When barley was fed alone, liveweight gain was reduced at feeding intervals of once or twice per week and there were signs of subclinical acidosis and scouring among sheep in these treatment groups.

Further evidence for the effectiveness of virginiamycin in controlling hindgut acidosis is shown in Figure 3. In this experiment 90% of the animals given wheat without virginiamycin had soft faeces and diarrhoea for at least 1 day and 60 % displayed this problem for at least 3 days. This compared with sheep given wheat with virginiamycin where only 20% of animals had soft faeces on the first day and things had returned to normal in all sheep by the third day.

It is clear from the summary in Table 2 that grains such as maize and sorghum are likely to deliver more starch to the hindgut than wheat, barley or oats. It is also apparent from the studies by Mann and Ørskov (1973) that when starch is consumed in large discreet meals there is a greater effect on fermentation in the hindgut than when it is continuously available. This explains the high incidence of diarrhoea in sheep fed grain supplements twice weekly. Under these conditions large amounts of grain are consumed in two big feeds each week and some starch is likely to pass undigested to the hindgut and cause acidosis and diarrhoea. Virginiamycin is likely to be particularly useful under these conditions.

Feeding management

Following the gradual introduction of grain over a 2 to 3 week period it is common then feed restricted amounts of grain at intervals of between 1 and 4 days. This is labour intensive and is also not ideal from the point of ensuring an even intake of supplement across large groups of sheep or cattle. Normally there is insufficient feed available for all animals to have a complete feed since the more aggressive animals get more than their share and there is insufficient left for the more cautious feeders. There are distinct advan-

Figure 3 Control of soft faeces and diarrhoea in sheep given wheat either with or without virginiamycin (Vm). From Murray *et al.* (1991).

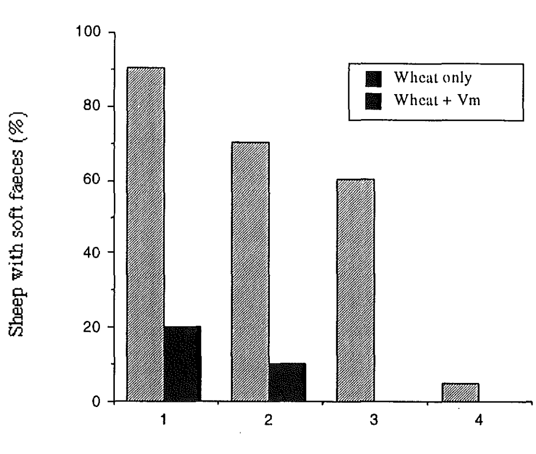
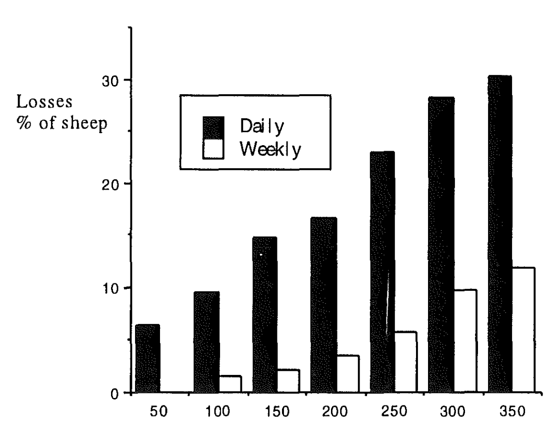


Figure 4 Losses when sheep were fed restricted amounts of wheat either weekly or daily (Franklin, 1952).



tages in feeding sheep at weekly intervals compared to daily since in weekly feeding sufficient feed is available for all animals to gain access to the supplement and even the more cautious (Figure 4, Franklin *et al.* 1952). With weekly feeding the high level of grain intake on the feeding means that animals need to be very well adapted to the grain feeding regime and the introductory procedure can take many weeks animals are suitably prepared for weekly feeding. On the other hand both cotton seed and lupins can be introduced into the diet at the desired level and without need for gradual introduction. It is also likely that virginiamycin will play an important role in making weekly feeding of cereal grain a safer and more attractive option.

One of the distinct advantages in feeding large grains such as lupins to sheep is that the grain can be fed out using a fertiliser spreader. This overcomes problems associated with trail feeding of lambing ewes where lambs are often left behind when ewes run after the vehicle to get to the grain first. Morecombe *et al.* (1988) reported no differences in performance when lambing ewes were fed daily in troughs or fortnightly using a super spreader. Similar trials have not yet been done using cereal grain and virginiamycin. It is possible that even sheep will not utilise smaller grains when fed out using a fertiliser spreader but we are not aware of any studies to explore this possibility.

Lupins, cotton seed and cereal grain with virginiamycin can be fed out at weekly intervals and with minimal requirement for gradual introduction. This makes these grains very easy to feed out. Provided that the amount of grain fed out each week is more than can be consumed in a single feed then there is likely to be an even level of intake by all animals across the mob. Cereal grain can also be fed to cattle in self feeders using fertilisers to limit the amount consumed. May and Barker (1984) have developed methods for restricting the amount of grain consumed by inclusion fertilisers such as urea, ammonium sulphate and diammonium phosphate. While these methods are potentially useful they require a gradual introduction for the animals to adapt to the high levels of urea. There is also a need for continual adjustment of fertiliser concentrations in order to achieve the desired level of grain intake and liveweight change. Possible contamination of fertilisers with heavy metals and toxic elements present in the fertilisers is an important consideration with respect to tissue residues. The use of phosphorous–containing fertilisers as limiters may present a more of a problem than the nitrogenous fertilisers.

Animal welfare

Excessive weight loss of livestock during drought and risk of death through starvation is unacceptable from an animal welfare perspective. On the other hand the risk of acidosis with grain feeding can lead to diarrhoea, flystrike and, in severe cases, death. These negative aspects of animal feeding are also clearly an animal welfare concern. The use of safer feedstuffs such as hay and silage, lupins and cottonseed is, therefore, widespread even although these options may be more expensive than cereal grains as sources of metabolisable energy. Reducing the risk of acidosis and diarrhoea with virginiamycin constitutes an important development not only in making the use of cereal grain more effective as a supplement but also more acceptable with respect to animal welfare.

Flexibility of being able to feed for liveweight gain

Supplements which contain high levels of digestible energy (*e.g.* lupins, cotton seed and cereal grain with virginiamycin and urea) can be used at restricted levels for maintenance and survival, or at higher levels for liveweight gain. This flexibility is a major advantage over roughage based supplements such as hay and silage which can only be used for maintenance and survival. Even good quality hay and silage fed to appetite only produce modest liveweight gain.

Reproductive Efficiency

Feeding for liveweight gain can be cost–effective where the aim is to improve reproductive efficiency or to finish cattle for slaughter. In feeding for reproductive efficiency we do not believe that there is any specific nutrient required. The key to reproductive efficiency appears to be adequate liveweight and condition score together with an adequate level of nutrition at joining. Response to supplements containing protein and/or urea are likely to be mediated through increased feed intake or more efficient fermentation and digestion rather than through meeting a specific need for additional protein. Supplementation with lupins, cotton seed or cereal grain with urea and virginiamycin are all likely to be equally effective and the choice of supplement would therefore depend very much on the cost of the various supplements, their availability and the logistical consideration of handling and feeding. The best returns from supplementary feeding of breeding animals is likely to come from feeding heifers to ensure that they calve at two years of age, and feeding first calvers to ensure that they mate successfully in their second breeding season. The cost of maintaining unproductive female animals is always high, but during drought, when feed is much more expensive, it is a cost which cannot be justified. The amount of feed required to maintain an animal is not all that much less than that required for growth. The additional amount of feed, or the improved quality of supplement, needed to achieve liveweight gain, compared to maintenance, in heifers and first calvers is likely to be a very good investment.

Table 3 Intake, liveweight gain and feed conversion of cattle fed a conventional feedlot diet with a gradual introduction to the final diet, an immediate or 'sudden' introduction to the final diet and a dietary regime in which restricted amounts of the grain concentrate with virginiamycin were fed once per week and long hay was available *ad libitum*. Diets with VM contained virginiamycin at a concentration of 20g/t. (Zorrilla-Rios *et al.* 1995)

	Gradual introduction Mixed	Sudden introduction Mixed + VM	Once weekly Grain + VM	s.e.d.	P
Average daily intake					
Grain kg/d	9.2	9.9	8.1	0.69	.09
Hay kg/d	2.4	2.3	2.6	0.39	.03
Total kg/d	11.8	12.6	10.7	0.71	.06
ME MJ/d	111.0	118.0	124.0	8.6	ns
ADG[a]	1.46	2.05	1.62	0.21	.01
ME utilisation[b]	82.6	80.5	99.4	11.2	.01

[a]Average daily gain estimated by regression of liveweights against time
[b]MJ ME/kg liveweight gain

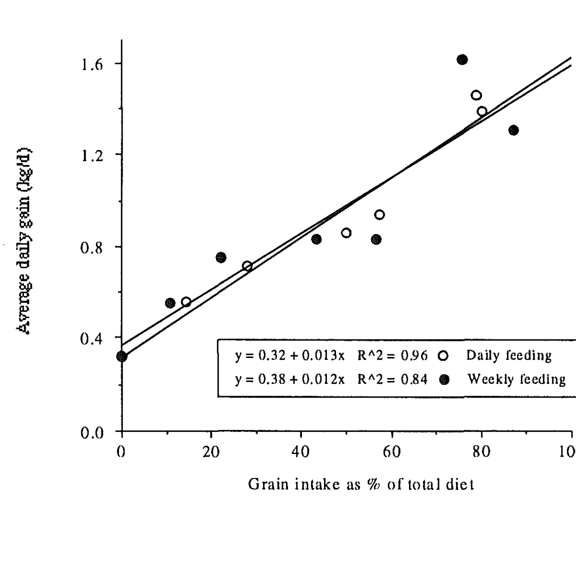
Liveweight Gain for Meat Production

The cost–effectiveness of feeding for liveweight gain in times of drought can calculated reasonably easily on the basis of feed costs, feed conversion efficiency, the relative value of the animals as stores and finished animals and the amount of liveweight gain required to finish the animals. There are normally a range of figures available for feed conversion efficiency and it is advisable to do your budgets on the more conservative figures so that risks of lower than expected performance are accounted for.

It is not necessary to confine animals in a feedlot if there is sufficient paddock feed to provide the roughage component of the diet. Providing the concentrate portion of the diet in self feeders in the paddock allows the cattle to regulate their own roughage intake. Alternatively roughage can be supplied in the form of large round bales if animals are being fed in a confined area. The data summarised in Table 3 shows the growth and performance of cattle fed a complete feed lot diet either, with a gradual increase in the amount of grain relative to roughage or with direct access to the final diet containing virginiamycin to reduce the risk of acidosis ('sudden' introduction). Table 3 also shows the performance of another group of cattle which were given the grain concentrate portion of the diet separately from the hay. Furthermore this concentrate portion of the diet was given once per week (56.7kg/week per head) to simulate topping up a self feeder on a weekly basis. Even although the intake of grain was less than in the case of animals fed the complete diet containing both hay and grain, the performance of the animals was similar. The potential to feed grain and hay separately provides a flexible method for opportunity and drought feedlotting. It removes the need to process the hay which simplifies the equipment required and gets away from the time consuming and unpleasant task of grinding hay.

Figure 5 shows responses in liveweight to increasing levels of barley grain fed either daily or weekly with virginiamycin. The conversion of grain to liveweight in the experiments summarised in Figure 5 is around 6.5 to 1. While more efficient feed conversion efficiency has been reported for supplements containing protein and urea it is suggested that part of the response under these conditions is due to improving efficiency of rumen function which increases feed intake. Data such as that shown in Figure 5 is for a basal diet which already contains sufficient nitrogen for efficient microbial activity in the rumen. It is absolutely essential to ensure that any feed supplement used for liveweight gain is well balanced and contains sufficient

Figure 5 Relationship between the proportion of grain in the diet and liveweight gain in cattle fed barley grain either daily or weekly with virginiamycin. (Rowe & Zorrilla-Rios 1993)



nitrogen and minerals to support efficient microbial activity in the rumen. If this balance is not achieved, and particularly if there is insufficient nitrogen and sulphur for the rumen microorganisms, growth rates and feed conversion efficiency will be below optimum.

The need to process cereal grains for ruminant feeding

Cereal grain does not need to be processed before feeding to sheep. Through primary mastication and rumination the grain is cracked and ground to allow efficient fermentation and digestion of starch. On the other hand for cattle it is widely accepted that the grain should be milled by grinding or rolling to expose the endosperm for fermentation and digestion. If this is not done a significant amount of grain passes intact through the digestive tract. The only exception is oat grain which can be fed whole without any adverse effect on productivity. For the other grains a general rule of thumb is that, if the cost of milling the grain is less than 30% of the cost of the grain then simple processing will be cost–effective.

Processing for Efficient Digestion and for Good Mixing

The question of how finely one should grind grain for cattle feeding is not entirely straightforward. Opinion on this issue varies from those who advocate just cracking the grain, using rollers or a hammer mill, to those who believe in fine grinding using a hammer mill. The particle size affects the rate and extent of fermentation in the rumen. The smaller particles are readily fermented in the rumen but are also likely to flow out of the rumen more quickly than larger particles. The fact that these two aspects of particle size work in opposite directions may explain why there is relatively little difference due to particle size on the proportion of dietary starch fermented in the rumen (Huntington 1994). As far as fermentation and digestion of the grain is concerned the main objective in processing grain should therefore be to ensure cracking of the grain in the most cost–effective way. It is however important to consider the process of mixing other ingredients with the grain. Grain which is lightly rolled or just cracked does not mix well with small amounts of minerals and feed additives such as urea, limestone and virginiamycin premix. The fine particles fall to the bottom during mixing and feeding out. This is particularly undesirable when using virginiamycin because it essential that it is consumed at the same time as the cereal grain in order to reduce the risk of acidosis.

Steam Treatment

While simple physical processing to crack the pericarp appears to be all that is needed to achieve optimal fermentation and digestion of wheat, there is evidence that steam treatment combined with rolling or flaking improves the utilisation of sorghum, maize and, to a lesser extent, barley. The digestibility of cereal starch is affected by the physical form of the starch and starch–protein associations. In the case of sorghum, steam and the physical forces of rolling are needed to disrupt the endosperm protein matrix to allow efficient fermentation and digestion. Steam flaking may increase the whole tract digestibility of sorghum from 87% in the case of dry rolling to around 98%. The corresponding difference for maize is around 6 percentage units and for barley between 2 to 5 units (Huntington 1994, Zinn 1993). On the other hand, steam processing of either wheat or oats gives no benefit over dry rolling or grinding (Huntington 1994, Zinn 1993). The effect of steam processing barley and wheat may actually be a disadvantage because this process increases the rate of fermentation to the point where it can lead to subclinical acidosis and a rise in the incidence of liver abscesses (Zinn 1993, 1994).

Opportunities for trading in grain

Grain can be easily stored, transported and there are a range of markets for it, including pig and poultry production domestically and the export market. This situation is very different to the market for hay and silage, which once purchased or made, is much more difficult to trade. The greater flexibility with which grain can be traded offers new opportunities for buying or storing grain at harvest which can then be used for drought protection, strategic finishing of steers, or supplementary feeding of heifers. Alternatively it can be sold at any stage if prices of grain indicate that this is the appropriate option.

Major objectives of a drought feeding strategy are to increase flexibility and minimise risk. It is likely that these objectives can partly be met by strategic trading in grain. Many graziers do not have facilities for trading, storing and processing grain. This means that many of the opportunities of buying grain at the right time and in quantities in which it can be transported and handled cheaply are not available to many individual graziers.

There are opportunities for graziers to work together with grain growers, a grain merchant or a feed company to purchase, store and process grain centrally. Benefits from this type of relationship include spreading risks over more than one industry and more than one commodity. It also makes it possible to use expertise in various aspects of producing, handling and storing grain, grain trading systems, animal production, feeding and the marketing of livestock. Making good decisions in response to changing prices for grain, cattle and other livestock products as well using appropriate mechanisms to trade grain in the most cost–effective way is not a simple task for a single operator. It is essential for the grazier to hold equity in the grain stocks in order to be able to stabilise income through having two related commodities to manage and trade. There appears to be few benefits to the grazier in dealing with a grain trader as a third party or paying consultants to advise on trading options.

Proper storage of grain can also be difficult for producers without the right equipment or expertise. Insect control is a very important issue since the use of any insecticides may have an important effect on meat residues. Quality control in grain handling and storage prior to feeding is something that every livestock producer should take very seriously. This aspect of quality control is even more important for smaller producers who may only use one or two silos of grain in finishing a small group of cattle. Under these conditions one 'bad' silo or load of grain could have a major impact on tissue residues.

Supply Issues

Cereal grain is produced primarily as a human foodstuff but the significant discounts for lower grade product means that there are opportunities to purchase feed grade grain on a strategic basis when grain is plentiful. With knowledge of feed conversion efficiency and estimated values of finished cattle it is relatively easy to determine a price which you can afford to pay for grain. Added to this should be storage costs. Grain should be bought or retained on farm when it is cheap as it is unlikely to be cost–effective to purchase it when there is a pressing demand to feed stock and prices are high.

Feeds such as lupin and cotton seed can be bought, stored and traded in the same way as cereal grain. On the other hand oil seed meals are more difficult to store and handle. These non–cereal supplements, like cereal grain, fluctuate markedly in price and availability and there are the same opportunities to trade in these commodities. It is the flexibility to cover a range of different commodities and production systems which appears to provide one of the best practical strategies for managing drought.

Potential for introducing weeds

Cereal grain are grown throughout Australia and it is possible to purchase grain either locally or from areas known to have minimum weed seed contamination. Lupin grain is grown in distinct areas and can contain weed seed such as double gee and radish. Cleaning the seed adds to its cost and is not always completely reliable. Cotton seed is almost totally free from weed seed contamination. Compared to hay the grain supplements are generally much safer in terms of their potential to introduce weed seeds to the farm. In the case of cereal grains it is far more likely that grain can be grown and stored on the same property or purchased locally and this minimises the risk of bring in new weeds.

Policies and incentives

In order to encourage graziers to increase their flexibility for coping with unpredictable periods of low availability of pasture feed it is suggested that there should be some incentives for holding appropriate drought reserves. There may also be incentives for companies and/or cooperatives to establish reserves in order to provide feed at reasonable prices to finish cattle in times of drought as means of maintaining cash flow for livestock producers and at the same time reducing stocking rates. For example, if the interest costs associated with storing grain were tax deductable it would be far more attractive to purchase grain strategically.

Conclusions

The development of safer ways to feed cereal grain to sheep and cattle creates new opportunities for using grain for a range of production options. It provides a means of feeding grain more safely under conventional management systems and opens up new options for finishing cattle and sheep. With the reduced risk of acidosis grain can be used more widely as an effective supplement under grazing conditions when the amount of pasture feed is scarce or of very low quality. Without a product such as virginiamycin strategic use of grain has been restricted to low–starch, high–protein grains such as cotton seed and lupins. Numerous producers with extensive experience of feeding lupins and cotton seed regard the returns from using these grains as highly satisfactory. With the potential to use cereal grains in the same way there may be even greater benefits as a result of their cheaper price compared to lupins and cotton seed.

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Accuracy of Climate Forecasting

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Summary

The variation of weather and climate takes place on a number of different time scales. The shortest of these are regarded as weather. The longer variations are known as climate—the longest of these occur on the scale of centuries or more. Our capacity to forecast climate is dependent on the time scale being considered. There are significant parts of the climate system, such as variations on the order of decades, which are poorly understood and for which there is currently no forecast capacity. On the other hand, two areas of climate which enjoy great current interest and research are the El-Niño-Southern-Oscillation (ENSO) which occurs on a time scale of one month to a year and 'Enhanced Greenhouse' which may occur on the time scale of centuries.

This paper explains some of the variability that is found in our climate records and explains the mechanisms leading to ENSO. ENSO is particularly important to the rural industry, because it explains, and allows the possible prediction of the occurrence of a large number of our drought and flood years. Current methods leading to El-Niño related climate predictions are based on historical correlations rather than physical prognostic models. Such prognostic models are being developed and should be available for forecasting purposes in perhaps five years.

Variability

It is useful to consider the different time scales on which the variability of weather and climate occurs (*see* Table 1).

Day/week variations

Forecasts are traditionally issued daily for 'today and tomorrow' with outlooks provided for about 3 days. The prognostic weather maps on which these forecasts are based are currently produced on computer and are improving as computers become faster and more powerful. In Australia four day forecasts are now being produced which are very good. They compare with the one day forecasts of approximately 25 years ago. Soon these may be available for 6 days. In the northern hemisphere models are now being extended to 14 days and some spectacular successes have been achieved. For example, an early warning of the Blizzard of 12–15 March 1993, which devastated the eastern

Table 1 Different time scales on which the variability of weather and climate occurs.

Variability	Known Major Causes	Economic Impact (Australia)	Forecasting Capability
Day/Week	Weather patterns	Immediate	Longstanding and improving
Month	Intra Seasonal Oscillation (ISO); or 30-60 day waves	High	Not fully understood - still subject of current research
Season/Year	El Niño/Southern Oscillation	High	Seasonal Outlook Service &- Australian Rainman - discussed in this paper
Decade(s)	Not well known	Potentially High	Nil
Century(s)	Greenhouse?	Potentially High	Research

United States was produced about 5 days ahead of its occurrence. The greater accuracy at longer ranges in the northern hemisphere is due to both the greater density of observations and the capacity of the US and European meteorological services to run 'ensemble' models. This means they run several runs of the models, with slightly different starting conditions, and then use the most common results.

Monthly variations

In the tropics there are semi regular atmospheric wave patterns around the globe which have become known by a number of interchangeable terms including Intra Seasonal Oscillation (ISO), the Madden Julian Oscillation, or the 30–60 day oscillation. The ISO shows some promise in assisting forecasts on the monthly timescale. Currently being researched.

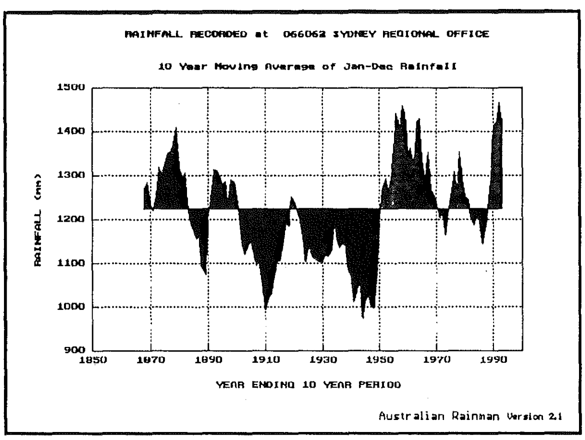

Figure 1 - Annual Rainfall Observatory Hill displayed using a ten year running mean.

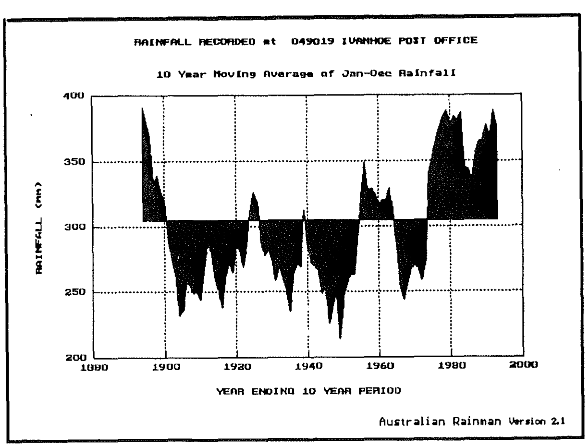

Figure 2 - Annual Rainfall for Ivanhoe, displayed using a ten year running mean.

Seasonal/annual variations

Great advances have been made in the last decade in the understanding of the El-Niño-Southern Oscillation (ENSO). ENSO affects the climate variability of a number of regions of the globe, including eastern Australia. During an El–Niño eastern Australia is frequently drier than normal, during a La Niña eastern Australia is frequently wetter than normal. Such extreme phases (ENSO or El Niño, anti–ENSO or La Niña) occur on average once about every 4 years. Current predictions are a statement of probabilities based on historical comparisons of the Southern Oscillation Index (SOI) and rainfall (*i.e.* a best–bet analysis of the information available).

The usefulness of the method varies depending on time of year and location considered. Indices other than the Southern Oscillation Index (such as Indian Ocean Sea Surface Temperature) have been investigated. In Australia climate research has focussed on rainfall. The effect of the SOI on plant growth is greater than the effect on rainfall alone. More needs to be done in relation to elements such as temperature and evaporation.

Variations on the scale of decades

There is great variability on the decadal time scale. If the rainfall record is displayed using a ten year running mean (*i.e.* smooth the data by progressive averaging over ten year periods) some interesting patterns appear. The ten year running means for Observatory Hill (Sydney), Ivanhoe, and Bega are shown in Figures 1 to 3. Much of New South Wales shows rainfall patterns similar to that of Ivanhoe and Sydney, with relatively high rainfall in the late eighteen–hundreds, relatively low rainfall during the first part of this century and higher rainfall during the last part of the century. There are no known explanations of this variability and therefore there is no current forecasting capability.

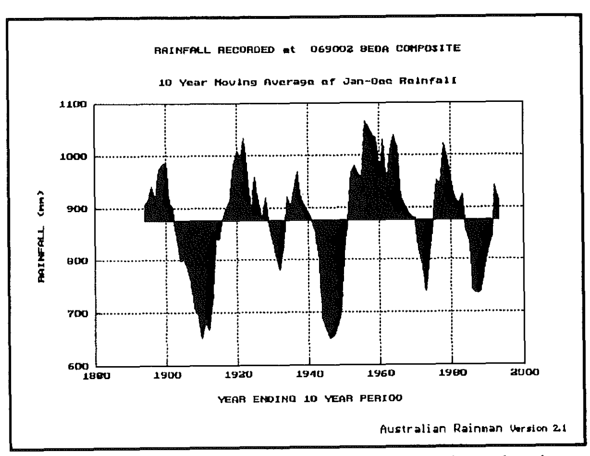

Figure 3 - Annual Rainfall for Bega displayed using a ten year running mean.

Long–term variability

There is considerable variability on the time scale of centuries or longer. Research on forecasting on this scale is mainly confined to the enhanced Greenhouse effect. This is not considered any further in this paper.

Influences on Australia's Weather and Climate

Australia's climate is amongst the most variable in the world. Factors influencing rain include monsoon rainfall, and tropical convection during the northern wet season, northwest cloudbands and frontal interactions (Autumn/Winter/Spring), ENSO as well as sea surface temperatures in the Indian Ocean and Timor Sea. This is shown diagrammatically in Figure 4.

The El-Niño-Southern-Oscillation (ENSO)

Brief explanation

Part of the variability in our climate has been attributed to the El-Niño-Southern-Oscillation (ENSO). This relates changes in sea surface circulation patterns and temperatures across the equatorial Pacific to atmospheric circulation patterns. This is shown in Figure 5 and can be summarised as follows:

- The cross ocean circulation patterns in the tropical Pacific Ocean are related to the cross atmosphere circulation patterns over the tropical Pacific Ocean;

- Normally waters to the NE of Australia form a 'hot spot'. Waters in the eastern tropical Pacific are relatively cool. Under these conditions the 'hot spot' evaporates moisture which forms clouds which are associated with rising air and a region of low pressure. In the eastern Pacific the air pressure tends to be high with descending air. The result is a cross–Pacific atmospheric circulation pattern, known as the Walker Circulation. This circulation pattern results in surface Easterly winds (the trade winds) bringing moisture to eastern Australia;

- Sometimes the waters to the NE of Australia are particularly warm and waters in the eastern Pacific are particularly cool. Under these conditions the Walker Circulation is enhanced, the trade winds are strengthened, bringing increased moisture to eastern Australia. The result can be unusually wet conditions for eastern Australia. The most recent example was in 1988/89. This type of circulation pattern is reflected in the typical location of 'Highs' and 'Lows' across the tropical Pacific. Typically, the atmospheric pressure over Darwin is relatively low whereas the atmospheric pressure over Tahiti is relatively high. An index known as the Southern Oscillation Index (SOI), which is a measure of this

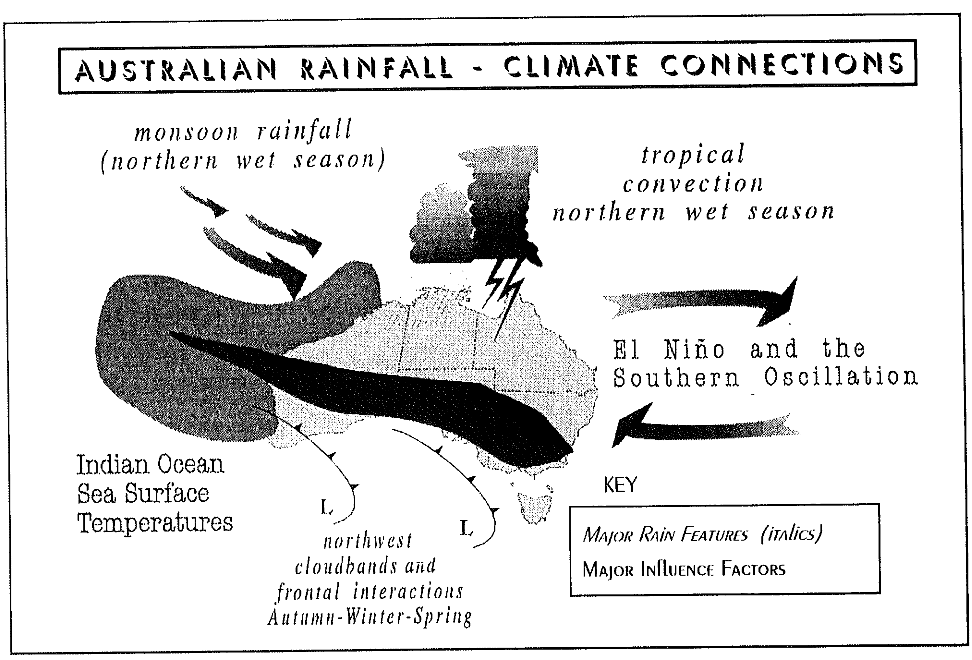

Figure 4 - Influences on Australia's Climate

pressure difference, tends to be high and positive (+5 to +30) in this situation which has been referred to as La Niña;

- Sometimes this situation is reversed. The waters to the NE of Australia are relatively cool, and the waters in the eastern tropical Pacific are relatively warm. The pressure over Darwin will be relatively high compared with Tahiti and the SOI will be large and negative (-5 to -30) . Under these conditions the Walker Circulation changes. The trade winds are weakened and in extreme cases may be reversed. Thus they do not bring moisture to eastern Australia. The result is drier than normal conditions. This type of situation has been called El Niño after the Peruvian name for the warmer waters which appear off the Peruvian coast around Christmas, hence El Niño for the Christ–child;

- Although no two El–Niños are the same, some generalisations can be made. The progression of a 'typical' El–Niño cycle is shown in Figure 6; and

- The acronym ENSO standing for El-Niño-Southern Oscillation is frequently used instead of El–Niño alone. The use of ENSO emphasises that the phenomenon is an interaction between the ocean and the atmosphere. With this terminology anti–ENSO is used instead of La Niña.

Relationships between SOI and rainfall

The discovery of the SOI–rainfall relationship is strong enough to be considered important for the explanation of, and possibly the prediction of, good and bad

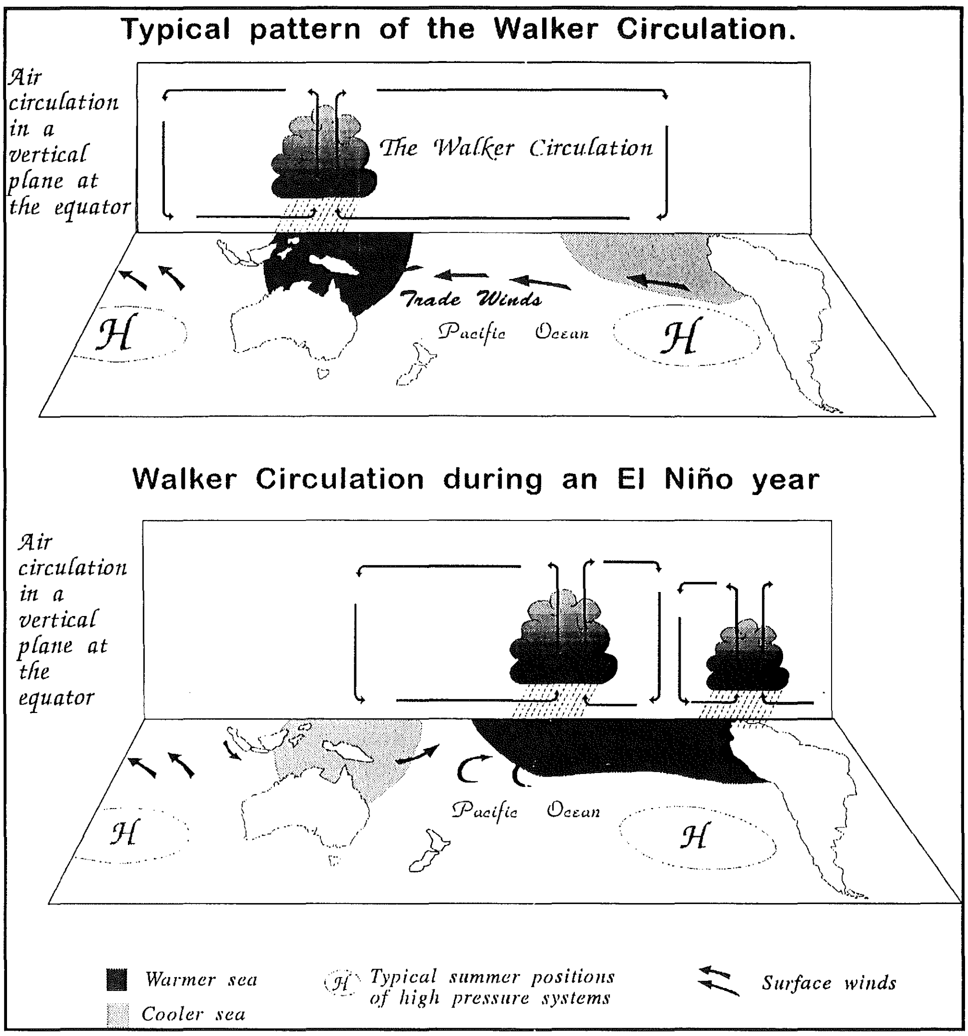

Figure 5 - Walker circulation patterns during El-Niño and normal years.

rainfall seasons. The relationship varies from location to location and from time of year to time of year. It tends to be better in winter and spring than in summer and autumn. There are, however, lagged relationships over different periods that can show good correlations as well as relationships between sharply rising and falling SOI and rainfall. For example, in Autumn, when use of the mean three monthly SOI is generally not useful, a sharp rise or fall in SOI can be a useful indicator.

Useful indicators can include the following:

1 Average SOI for three months for indicating rainfall next three months;

2 Average SOI for three months indicating rainfall for three months with a lag of six months;

3 Sudden rise or fall in SOI as an indicator for rain in the following three months; and

4 average SOI for three months as an indicator for the next year.

Prediction of the SOI

At this stage the SOI is not predicted, the historical SOI (now calculated back to 1870) is used and compared with historical rainfall data. The result is an expression of rainfall probability which is a measure of historical occurrence. Much research is being devoted to methods for the prediction of sea surface temperatures and SOI. This requires coupled ocean–atmosphere general circulation models, run at high grid resolution and short time steps for periods of one month to a year. These models are similar to those used for Greenhouse research but at higher resolution. Results from such models are now being used, but much work is needed. By using ensemble techniques for these models meteorologists may eventually (perhaps in about 5 years) be able to produce true seasonal forecasts. In the meantime, seasonal predictions are really a statement of past probabilities under similar circumstances.

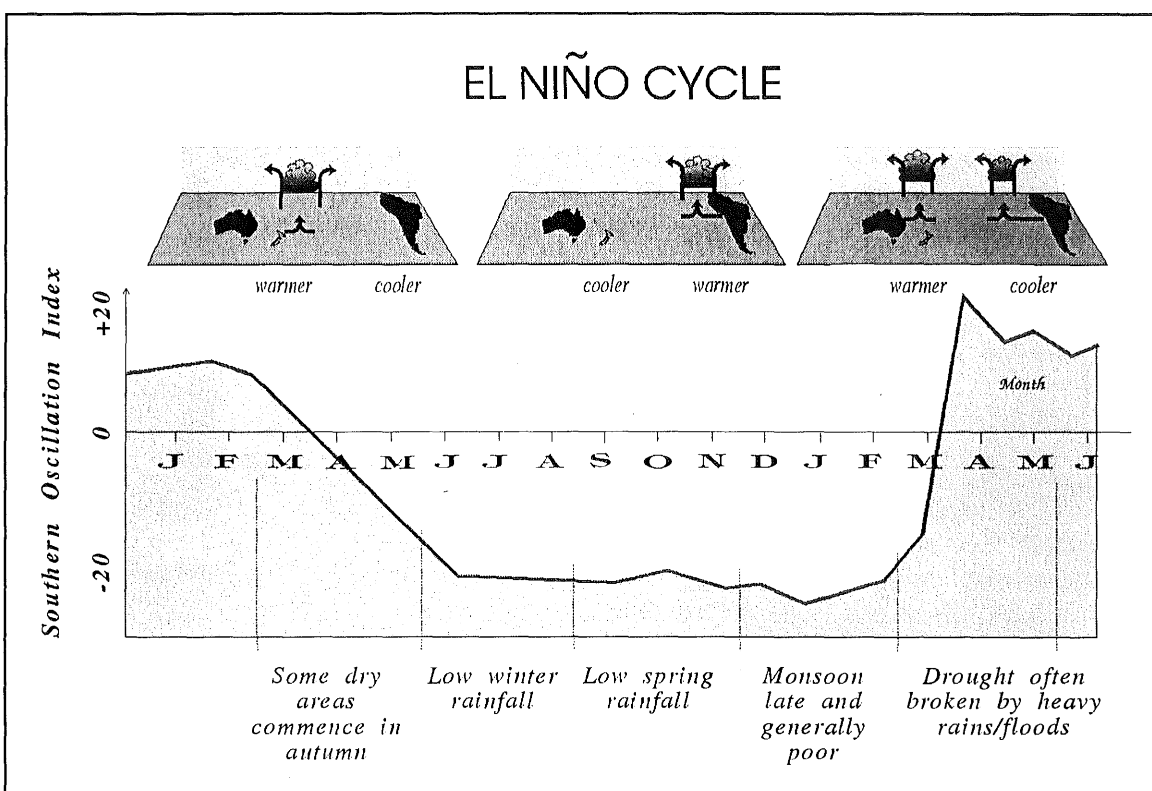

Figure 6 - "Typical" El-Niño Cycle

How to use SOI information

Telephone and Facsimile guidance: - Information services are provided by :

Bureau of Meteorology
Poll Fax: 019 - 725 251, and

Queensland Department of Primary Industries:
Phone : 07 - 877 9602
Poll Fax: 019 - 725 301

Seasonal Climate Outlook—The historical SOI and rainfall data, together with some information from Indian Ocean sea surface temperatures as well as some SST predictions which are currently provided from some of the computer models are used in the preparation of the Bureau of Meteorology's 'Seasonal Climate Outlook' (SCO). Study of the probability tables in this publication will give readers some idea of the confidence of outlook information. For 'normal' conditions (or near zero SOI) the rainfall distribution is 30% below average, 40% within average ranges, 30% above average (30/40/30). The degree to which probabilities vary from this give an indication of how strong the indicators are at any one time. The media release only, front page of the SCO, gives only very limited information.

Australian Rainman—A joint effort of the Bureau of Meteorology, Queensland Department of Primary Industries and WA Agriculture. SOI information is also contained in the computer program 'Australian Rainman'. It allows one to look at historical rainfall probabilities for selected SOI periods . The beauty of this program is that the user can select different SOI periods and have a look at what happened historically. If the probabilities show a strong shift from the so-called 'normal conditions', different planning options might be considered, compared with options considered when probabilities are close to 30/40/30.

- When historical SOI–rainfall information is used as a predictor for future climate behaviour, it is important to realise the probabilistic nature of the predictions. For example even in periods with large negative SOI, there will be a significant number of occasions when the rainfall will not be low; and

- During periods when the SOI is within +5 to -5, rainfall can be expected to behave as per the long term average. Both droughts and floods are possible, but will not be due to ENSO related causes.

Australian Rainman Examples

It is useful to look at some examples of rainfall probability derived from *Australian Rainman* . The following graphs are for Cobar. From Figure 7 it can be seen that the probability of rainfall during spring is strongly related to the SOI during winter. For example there is a 26% probability of obtaining 75mm if the winter SOI is -5 or less, 50% probability if the winter SOI is between -5 and +5 and 75% probability of having 75mm if the SOI is greater than +5. On the other hand Figure 8 shows a period when the SOI has very little influence on the rainfall at Cobar.

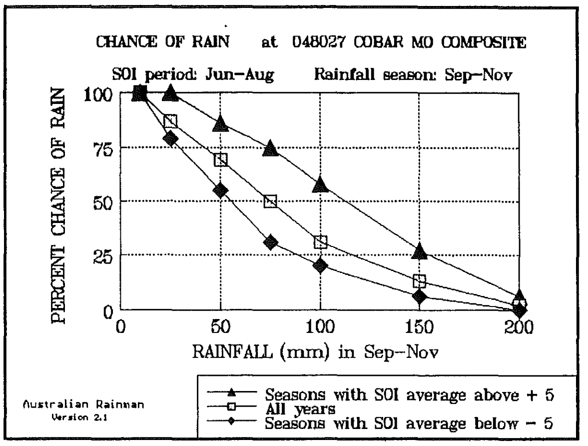

Figure 7 - Winter SOI as indicator for Spring rainfall

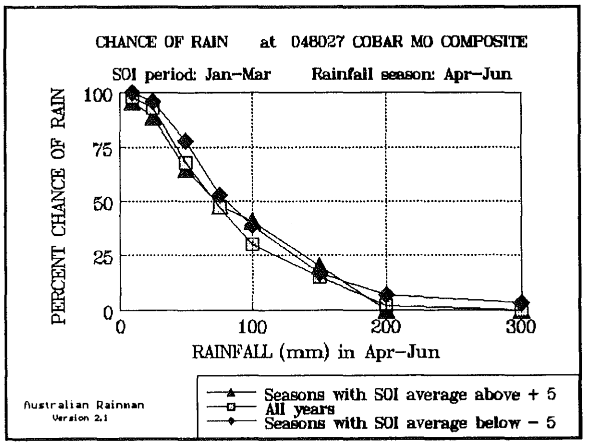

Figure 8 - Jan-Feb SOI as indication for April - June rainfall

Accuracy of Climate 'Forecasts'

It is important to take into consideration the following points when trying to assess the accuracy of current climate forecasts:

- These are essentially restricted to rainfall and are based only some of the known factors influencing our rainfall;

- Predictions are not forecasts in the sense we use them for weather forecasts. They are a statement of probability based on past occurrences. This is subtly but significantly different;

- There are significant differences in the probabilities and correlations obtained between seasons and between different locations. There can also be differences depending on the state of SOI. For examples at some places, during some seasons a large positive SOI can have significance whereas a large negative SOI may not; and

- Analysis of the Seasonal Climate Outlook has shown varying success for different methods using the SOI throughout Australia. Figure 9 shows the start month of the most skilful 3 month forecast (neglecting the dry season) during June 1992–October 1993.

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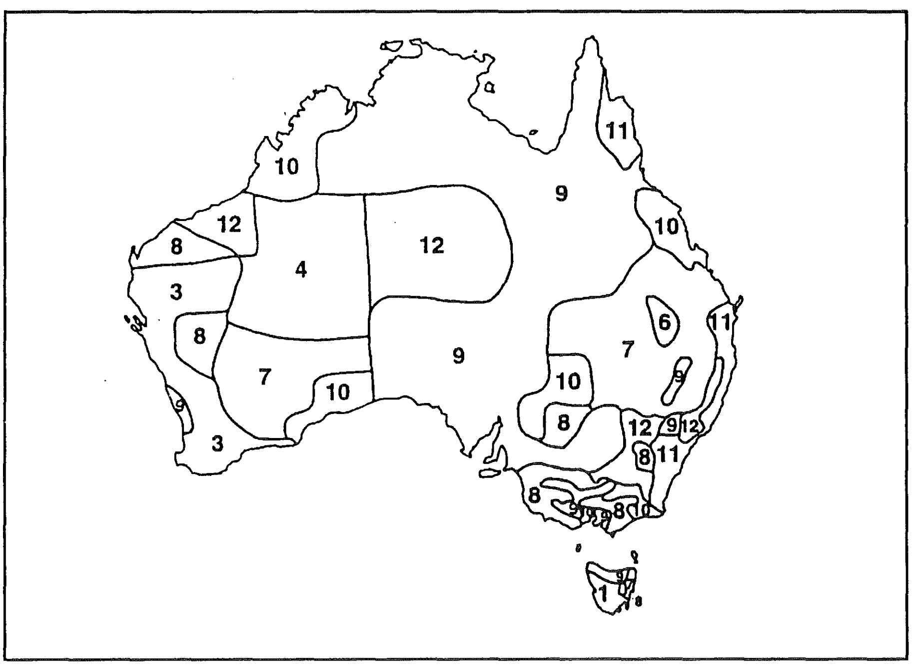

Figure 9 Highest Skill Map

The Place for Molasses in Drought Feeding Strategies

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Summary

Molasses has been used as drought feed for one hundred years. It is an energy supplement and needs to be balanced with protein meal or urea and sometimes salt and phosphorus. A simple, effective supplement is molasses and 8% urea to maintain weight and a mix of molasses, 3% urea and 8 – 10% protein meal will ensure weight gain. The supplements are cost–effective in areas within 500 – 800km of sugar mills. Molasses supply is stable and production from the mills coincides with times of peak demand.

Molasses is the basis of an effective and cost–effective drought feeding programme. The system is simple and easily managed on property. There is moderate capital investment in farm storage and a mixer. This investment can be used to value add cattle when drought conditions are absent.

Preamble

The old adage in drought management is to sell, agist and then feed. The timing of these decisions can be critical to the successful management of a drought. There are situations where selling is unattractive due to low prices and agistment may be unobtainable due to a generalised feed shortage. Beef producers may have to feed because the other alternatives become difficult or impossible.

Introduction

The role of molasses as a drought feed in Queensland and Northern NSW has been reviewed by Wythes and Ernst (1984). This paper summarises the well established information on molasses feeding and highlights developments during the past 10 years. The main emphasis is on the use of molasses as a cattle feed under Queensland conditions.

Feeding concepts

For large areas of Northern Australia the wet season brings an abundance of pasture which hays off to give low quality roughage and a shortage of protein. This feed source can run out due to lack of summer rains on normal dry season grazing and lead to a shortage of dry matter and drought conditions.

There are three tactics to manage these conditions:

Strategic Supplements

- Long term low level;
- Low cost per day;
- Start May/June.

e.g. dry lick of salt, urea and P; molasses urea drum rollers; blocks.

Crisis Supplements

- Short term, higher level;
- Higher cost per day;
- Start August, September or October.

e.g. protein meals; high intake blocks; molasses, urea supplements.

Production Feeding

- Short term (3–4 months);
- High cost;
- Target groups to value add.

e.g. grain or molasses, urea and protein meal.

Strategic supplements are widely used every year to reduce weight loss and with added protein meal may sustain or improve cow fertility. This long term low level supplementation may be inadequate to ensure survival if the dry season is longer than normal and feed is short. The beef producer may then have no choice but to feed a crisis supplement.

Crisis supplementation can be a planned activity and it also copes with the situation where cattle are in too low a body condition for anything else to work. The aim is to hold off feeding until there is a loss in body condition. This means that crisis supplementation is not required in all years. The supplement is designed to provide enough nutrients to improve body condition.

Production feeding is seen as a paddock alternative to feedlotting and classes of cattle are chosen which will be marketable within 3 – 5 months of feeding. Examples are finishing bullocks in October – December and finishing cull cows in August – September.

Molasses as a Drought Feed

Molasses in the liquid form is freely available from sugar mills along the Eastern seaboard from far North Queensland to Northern NSW. From 1995 molasses will also be available in limited quantities from Kununurra in WA.

Biology and efficacy

Molasses contains 20 to 25% water and has a metabolisable energy content (ME) of 8 to 9 MJ/kg fresh weight. This rates 1kg of grain equivalent to 1.5kg molasses on an as fed basis.

Molasses is high in energy and sulphur but has the disadvantage of being low in nitrogen (N) and phosphorous (P), high in potassium and produces a less efficient butyrate type fermentation when fed to ruminants.

To balance the supplement of molasses, urea or a protein meal is added to provide extra N, Salt, P and a rumen modifier (*e.g.* monensin) will improve utilisation.

Supplements

There is a well established tradition of using a molasses, urea and water mixture in a drum roller dispenser to provide long term, low level supplements. Nowadays drum rollers are used less frequently and blocks or salt, urea dry licks have become more popular.

Cattle supplemented using drum rollers maintain liveweight or gain up to 0.2kg/day.

Crisis Supplements—Molasses Plus 8% Urea (M8U)

It has been known for a long time that addition of urea is an effective means of controlling the intake of molasses. (Beames, 1960). However, it was not until the advent of mechanical mixers that molasses and urea were fed in open troughs. The mechanical mixing is essential to ensure that all ingredients including urea are properly mixed and the cattle thus have an even intake of supplement. Nicol, Venamore and Beasley (1984) reported the first commercial use of M8U (molasses plus 8% urea) in the Mackay district during the 1979 – 1983 drought. M8U is now a widely used crisis supplement and is available pre-mixed from at least one mill in Queensland.

Table 1 shows the expected intakes and gains of various classes of cattle on poor quality pastures supplemented with ad lib M8U. Very little or no substitution effect can be expected when feeding M8U on pastures providing less than a maintenance level of nutrition.

Crisis Supplements (molasses and protein meals)

Some beef producers do not have access to a mechanical mixer or prefer not to use urea. The choice for them is to mix 8 – 12% protein meal with the molasses to achieve a result similar to or better than M8U. Protein meals used have included cottonseed meal, meat and bone meal and sunflower meal levels of feeding and expected liveweight gain are summarised in Tables 1 and 2.

Production Supplements

Production feeding is an alternative to feedlotting with cattle being supplemented in the paddock. The objective is to add value to selected groups of cattle over a period of 3 – 5 months. There is a real benefit of extra cash flow during drought and a freeing up of country for other stock after the drought is broken.

Table 1 Estimated supplement intakes and liveweight gains of cattle grazing dry feed, losing 0.2kg/day, fed ad lib M8U.

Class of animal		Intake kg/day	Liveweight gain kg/day
Weaner	(180kg)	1.5	0.2
Yearling steer	(300kg)	2.5	0.3
2 year old steer	(400kg)	3.5	0.3
3 year old steer	(500kg)	4.5	0.4
Mature breeder		4.0	0 – 0.3

Table 2 Estimated supplement intakes and liveweight gains of cattle grazing dry feed, losing 0.2kg/day, fed ad lib molasses fortified with protein meal, phosphorus and 3% urea.

Class of animal		Intake kg/day	Liveweight gain kg/day
Weaner	(180kg)	3.2	0.43
Yearling steer	(300kg)	8.0	0.60
2 year old steer	(400kg)	10.5	0.70
3 year old steer	(500kg)	11.2	0.70
3.5 year old heifer	(400kg)	10.0	0.90

The selected cattle may be cull cows in store condition in May/June or steers in forward store condition in the liveweight range 480 – 520kg.

The practice of using molasses based production rations was pioneered by several producers including one based in the Burdekin during the early 1980's (Lindsay, 1995). The pioneers used molasses, meat meal mixture to finish Brahman crossbred steers for local and export markets.

Work at Swan's Lagoon Research Station (Lindsay, Dyer, Gelling and Laing, 1994) refined the ration used to incorporate molasses, 3% urea 8 – 10% protein meal, 1% dicalcium phosphate 1% salt and the rumen modifier, monensin. This balanced supplement was necessary to achieve optimum growth. The expected performance is shown in Table 2.

Additional Production Benefits of Supplements

There is practical and experimental evidence that supplements of M8U or molasses plus protein meals given during the period six weeks prior to calving will increase weaning rates in the next season by 10 – 15% (Fordyce 1992). Supplementing weaners with M8U will also boost yearling and two year old liveweights.

Farm management issues

The primary concern of the beef producer is to ensure the viability of the enterprise by reducing cattle mortalities and having cattle to sell and breeders to bred from in the future.

Economics

The money to buy supplements may come from cash reserves or as is more often the case from an overdraft. Thus producers will seek to delay feeding and use the cheapest option available at the time the decision is made to feed. The common problem is that producers retain too many cattle for too long and then depend on crisis feeding.

Table 3 represents the cost of various supplement strategies for breeders and can be used as an aid in decision making.

On an annual basis the strategic supplement costs only 37% of the cost of crisis feeding. However, over a 10 – 20 year period the cost of using a crisis supplement may be the same as or less than strategic supplements. This will be so if the probability of the need for crisis feeding is 1 year in 3. It should be noted however that it is possible to have 3 consecutive drought years in 10.

In the example in Table 4 there is a net profit of $80/head. This has been shown over the past 3 years to vary from 0 – $120/head depending on beef prices. The calculation has not included the effect on overall debt reduction or the value of the extra grazing available for other cattle since these cattle have left the property.

One other factor which is hard to put a dollar figure on is the peace of mind achieved by supplementary feeding of stock which would otherwise die.

Storage, Handling and Feeding

Storage on Farm

Fresh molasses is available from sugar mills from June to early December each year. This coincides with peak demand for drought feeding. Producers can obtain molasses in bulk tanks, their own tanks on trucks or in 200 litre drums. There is an increasing trend for on farm storage of 40 – 60 tonnes with contractors using semi–trailers (22 tonnes) or B doubles (40 tonnes) to fill on demand.

Pumps are used to empty into storage in most cases. However there are efficiencies to be obtained when gravity is used to unload not only into the on-farm mixer but also from the bulk transport. It may take 3 hours to pump out a semi–trailer compared with minutes for a gravity dump.

Table 3 Indicative costs of various strategies for the supplimentary feeding of breeders.

Supplement	Cost/day (c/d)	Cost/head for feed period ($/head)* Strategic	Crisis
Drum roller	5.6	11.80	
M8U	35.6		32.00
Molasses, PM†	35.6		32.00

*Assumptions:
A strategic feed period of 7 months and a crisis feed period of 3 months;
Molasses @ $85/tonne;
Urea @ $500/tonne;
Cottonseed meal @ $480/tonne(PM);
†Molasses + 8-10 % protein meal.

Table 4 The benefit-cost analysis of production feeding a 500kg steer.

	$
Initial value	420
Feed cost	132
Realised value	632
Nett profit	80
BCR	1.65 – 1

Assumptions:
100 days feeding @ 10kg/day of ration costing $132/tonne.

Handling

Molasses is carted around the property in smaller tanks which usually incorporate a paddle mixer driven by a petrol engine.

The mixers usually vary from less than 1 – 8 tonnes and are mounted on the tray of a utility or truck or on a separate trailer.

A calibrated dipstick measures the amount of molasses required then additives are put on top for mixing. Measures used include full bags or volume measures varying from a 3 litre ice cream container to a 20 litre pail but volume measures should be calibrated on the weight they hold.

The mixed supplement is fed out in open troughs (exception is drum rollers) which vary from hollow logs to 200 litre fuel drums and concrete troughs.

Molasses Storage Problems

Daly (1983) reviewed the issues involved in storing molasses for extended periods. Molasses direct from the mill has been pre–cooled. However in the next two months chemical reactions produce heat and carbon dioxide. The frothing is usually quite evident and allowance has to be made in storage for some expansion of the molasses. The atmosphere within the tank for this first 2 months is regarded as unsafe for humans.

Once the molasses has stabilised it can be stored on property for at least 6 – 8 months provided rain and other contaminants are kept out.

Feeding Management

The molasses mixtures described above are very acceptable to cattle. Nowadays with mechanical mixers there is no build up phase so cattle are put onto the standard mix from the first day. Problems of toxicity usually only arise if cattle are fed straight for a while before urea is added.

The issue of variability of individual intake across mobs has been talked about for a long time. A research project funded in part by the MRC (Dixon, unpublished) is now underway to answer such basic questions as trough design, spacing and area per head.

Frequency of feeding M8U and molasses urea and protein meal has been studied only in a cursory manner. Observation from the field indicate that it is possible to feed M8U and MU+CSM (cottonseed meal) twice a week as a means of reducing feed intake. The results suggest that it is safe during non-rain periods.

The disadvantage of twice weekly feeding is that cattle expect to be fed every day to be feed day and wait around the troughs especially when vehicles are around. In contrast a feature of the more usual ad libitum feeding is that the cattle have a lick and go.

Producer acceptance

Producer acceptance of the technology is high. This is evidenced by sales of molasses mixers and the sales of molasses during drought years. For example, it is estimated that in 1982 100,000 tonnes of molasses was used to feed 400,000 cattle (Daly and Schmidt, 1984). In 1992 and 1994 the estimates are double that over 200,000 + molasses was used for cattle feeding.

Regional and national issues

Molasses supply

In the past two years the Australian Molasses Pool has been re–organised to become Australian Molasses Trading. This group is the single desk seller of molasses on the export market and runs all the bulk export terminals.

There is a free market for domestic sales of molasses. Molasses is used on the domestic market mainly for fermentation and stockfeed usually in the ratio of 2:1. However, more molasses is used in stockfeed during drought years.

Several companies have actively sought stable domestic markets by becoming involved in adding value to molasses. This has involved building distribution storages in the feedlot belt for the marketing of molasses based premixes to the feedlots. Other companies mix urea at the mill and market M8U mixes direct to producers. It should also be possible to ship molasses to service other potential markets around Australia.

Effective competition has also meant that pricing varies between mills depending upon the alternative prices of local feeds.

A Commonwealth and State Government scheme was set up in 1982 to build molasses storages at inland locations to meet the needs of a wide group of producers. Four such storages were built. Since then free enterprise has largely taken over with inland storages at *e.g.* Mt. Garnet (North QLD) providing molasses at a price competitive with and sometimes cheaper than coastal mills.

Occasionally the State Government has stepped in to import molasses when supplies were in danger of running out. There is always a high risk with this venture that the molasses will become unsaleable overnight if the drought breaks. With this in mind molasses sellers now require a deposit to order imported molasses and sugar mills have sold options to producers to guarantee out of season supply (from December – May).

It is clear that the various sugar milling companies recognise the important community benefit in meeting the somewhat variable demand for molasses for drought feeding,

One of the future trends is likely to be a continuation of the options system where producers buy a set amount of molasses per year at a more competitive price. In drought years molasses will be fed to keep cattle alive and in other years it will be used for production feeding during the dry season and so improve cattle selling options. There are also recent calls for storage facilities at ports such as Newcastle to service the Hunter Region.

Maintaining the Core Breeding Herd

Molasses based supplements together with whole cottonseed have been used widely in the past 3 years to maintain core breeding herds. This allows a more rapid return to normal herd numbers when the drought breaks. It has also helped to keep people on their properties and reduce demand on social services.

Unplanned Side Effects

Molasses itself is not known to introduce pests, weeds or chemical residues. Cottonseed meal and the other protein meals have not been found to contain any residues likely to contaminate meat. Thus both locally produced and imported molasses appears to present a minimal threat to product quality.

Cattle consuming molasses–based drought supplements will continue to eat dry pasture. The manager is responsible for ensuring that the pastures are not overgrazed.

In any situation where cattle are fed molasses supplements, indigenous animals such as marsupials also have access to the supplement. This has a positive effect on them in that deaths are reduced and reproductive processes continue.

Finally, supplemented cattle are generally much quieter and easier to handle.

Conclusions

We have demonstrated that molasses is the basis for effective and cost effective drought supplements. The system is simple and easily managed on individual properties. With a moderate capital investment in storage and a mixer the equipment can be used for saving cattle in a drought and adding value to cattle when conditions are normal.

The current free market in molasses supply is sensitive to demand but there is scope for more inland storages to make molasses feeding economical for a greater range of producers.

There appear to be few negative side effects of the system provided grazing is managed well. Indeed, molasses is pivotal in the survival of large numbers of cattle during severe droughts.

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Straw and Low Quality Roughages as Drought Feeds

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Summary

Cereal crop residues and dead mature pasture are often the primary feeds available to maintain stock during drought. Although of low nutritional value, their advantages are in their availability and in most circumstances their low cost. Costs for baling and transport may make straws more expensive per unit of metabolizable energy than grain or molasses.

On farms with abundant roughage of low quality, the principal issue becomes how to utilize this roughage most effectively. On farms with a shortage of any feed, the principal issue will usually be to estimate the nutritional value (particularly of energy) of the available roughage compared to purchased feedstuffs.

Constraints on the use of straw and dead mature pasture include the need to avoid over–grazing, low nutritive value and low voluntary intake, and high costs for baling, transport or chemical treatment to improve nutritional value.

Nutritive value of low quality pastures and cereal crop residues varies widely. Leaf content of straws is usually the most important characteristic determining their value. Most crop residue is utilised by grazing the stubble. Intensive selection of the more digestible parts of the stubble means animals are likely to maintain liveweight (LW) for some weeks or months after being introduced to stubbles. However, later LW losses may be severe. Availability of small amounts of green plant material after storms has a major effect on the productivity of animals grazing stubbles.

Supplements based on non–protein (NPN, *e.g.* urea) nitrogen and sulphur (NPN/S) can reduce rates of LW loss and improve reproduction rates of animals grazing stubble or dead mature pasture. Little response to NPN/S supplements may occur if:

- The quality of ingested roughage is adequate due to selection;
- Animals cannot select roughage high in leaf; and
- difficulties with delivery of supplements results in many animals consuming little supplement or there is poor synchrony of supply of substrates in the rumen.

The value of NPN/S supplements is principally to reduce mortality and to delay the need to implement alternative higher cost feeding and management strategies.

Introduction

Most of the roughage available during drought will consist of dead mature pasture or crop residues and will be of low nutritive value. In this paper we consider the use and feeding management during drought of low quality roughage, and in particular cereal crop residues to maintain sheep and cattle. These principles will also apply to residues from grain legume crops, although the amount of spilt grain is likely to be a more important issue.

Predicting the nutritional value of low quality roughage will be most important when it provides most of the feed intake. This will usually happen where the priorities are for survival and reproduction of the breeding stock and slow growth by animals in the growing-out phase.

When high growth or productivity are required low quality roughages cannot be used as the major part of the diet simply because they are too low in nutritional value. For high productivity, feeds such as grain, silage and molasses will have to be used as the basis of the diet.

The factors determining the value of low quality roughages as drought feeds will vary depending on the situation. One scenario is where a farm has abundant roughage available as dead mature pasture or crop residues, but the nutritive value is too low for the required level of animal production. The principal issue becomes how to use this roughage most effectively for survival of the breeding herd, or as part of the diet for a producing animal. High production rates will require high levels of molasses, grain or protein meal supplements, and will not be discussed in this paper.

A second scenario will occur where a farm has a shortage of any feed, including roughage. The principal issue becomes one of understanding the value of available straw or stubble in comparison with purchased hay or other feedstuffs.

The obvious advantages of straws and low quality roughages are their availability, and in most circumstances, their low cost. Grain production records give reasonable estimates of the amounts of straw available, since the amount of straw produced will usually be 1.0–1.5 times the amount of grain. Wheat is by far the most important crop with an average production during the last two decades of 14 million tonnes (range 9–22), followed by barley (4 million tonnes, range 2–7), oats (2 million tonnes) and sorghum (1 million tonnes). In drought years national production can be half, and presumably within regions much less than half, of average production.

The cost of straw per unit of metabolizable (ME) energy is usually, but not always, less than for grain or molasses. Stubble or dead mature pasture has no alternative value. However baling, handling and transporting straw can often substantially increase the cost of straw per unit of metabolizable energy (Table 1). For example, contractor costs for merely baling straw are likely to be $30 – $50 per tonne. With some additional costs for transport and for wastage (especially during feeding), baled straw can cost $40 – $80 per tonne and thus be more expensive per unit of metabolizable energy than grain or molasses.

Constraints

Sustainability

There will always be a need, albeit often ignored, to retain sufficient crop or pasture residues to protect soils from wind and water erosion during and/or immediately following drought, and to maintain satisfactory levels of soil organic matter. Recommended levels of retention have been established for various systems. Over–grazing, particularly during drought, may also have major adverse consequences by elimination of desirable perennial species, encouragement of woody weeds and by changing the balance of pasture species present after the drought. The consequences on pasture productivity and the sustainability of the grazing system are long–term (Scott 1995).

Low nutritive value of crop residues

Most crop residues and dead pastures are of low digestibility and contain low concentrations of nitrogen, sulphur, phosphorus and other minerals. Voluntary intake is usually low (less than 2% of LW), partly because of low digestibility (less than 55% dry matter digestibility) and nutrient content, but also because of limitations associated with physical breakdown and passage of highly fibrous material through the digestive tract. Even when digestibility and nutrient content are acceptable, palatability of the material may limit voluntary intake, *e.g.* for the thick stems of sorghum and maize. Plant anti-nutritional factors or microbial growth on crop residues (*e.g.* the fungus *Phomopsis leptostromiformis* on lupin stubble) may also be limiting factors.

The low ME content of crop residues (4 – 7 MJ ME/kg DM) sets severe limits on their use, since even if voluntary intake can be increased to, for example 3% of LW, intake of ME will still be sufficient only for maintenance or slow growth. The extent to which this is a constraint depends on both the required type and level of production (survival, reproduction, slow LW loss, slow LW gain) and the economic consequences of achieving this in various situations.

Table 1 Comparisons of cost per unit of metabolizable energy (MJ ME) of baled straw, grain and molasses for various prices per tonne of these feeds.

Baled straw		Grain		Molasses	
$/tonne	Cents/MJ	$/tonne	Cents/MJ	$/tonne	Cents/MJ
20	0.3-0.6			60	0.7
40	0.6-1.1	100	0.9	90	1.0
60	1.0-1.7	150	1.3	120	1.4
80	1.3-2.2	200	1.7	150	1.7

Assumed contents of metabolizable energy: Straw 4-7 MJ ME/kg DM;
Grain 13 MJ ME/kg DM;
Molasses 11.5 MJ ME/kg DM.

Additional costs for transport are likely to be: Straw 0.20 cents/MJ ME per 100 km;
Grain 0.04 cents/MJ ME per 100 km;
Molasses 0.05 cents/MJ ME per 100 km.

Storage, transport and modification of crop residues

The low nutritive value and bulky nature of crop residues means it is seldom economically viable to invest in large additional costs for packaging, storage, transport, or modification. Hence, generally crop residues can be used for livestock only when produced in mixed livestock/cropping areas. Transport costs per unit of ME are much higher than for grain or molasses due to the combination of low ME content and low bulk density.

Treatment of low quality roughages, including crop residues, with alkalis has been shown to effectively increase digestibility and intake. However, considerable inputs are required to produce a feedstuff which at best only provides sufficient energy for maintenance or slow growth. Furthermore, the increase in digestibility is inversely related to the digestibility of the material before treatment and digestibility of alkali-treated roughage is seldom greater than about 55%. Other problems are that the strong alkalis such as sodium hydroxide are dangerous to handle, and in some areas the additional excretion of sodium will not be acceptable for environmental reasons.

For a treatment system to be useful under Australian conditions it will need to be simple and involve low capital investment. Injection of large round bales with aqueous ammonia or solutions of alkali seems to meet these criteria. This method of treatment of barley straw appeared to be very successful under one set of experimental conditions, with increases in intake of straw by 36% and in ME content by 53% (Stephenson *et al.* 1984). However in other experiments (Aitchison *et al.* 1986) a poor response was observed when wheat straw was similarly treated. Further work is needed.

Grazing stubbles

The most common system of using crop residues in Australia is no doubt by grazing stubbles in situ. This situation does not seem likely to change. However utilisation of crop residues by grazing introduces a number of limitations:

- Only crop residues in mixed cropping/livestock areas are likely to be used since areas engaged only in cropping do not usually have essential infrastructure such as fences and stock water;

- There will be little flexibility in the time frame during which stubble can be used, since utilisation can only be between the grain harvest and the time when the land will have to be prepared for the next crop;

- Both the quantity and the nutritional value of stubbles are likely to decline rapidly after harvest due to leaching and decay, especially with any rain. Under Western Australia conditions Purser (1982) observed that DM digestibility declined by 5 percentage units with each six weeks post–harvest. There is also the risk of complete loss of stubble by fire; and

- Only a small proportion of the total stubble can actually be consumed by stock.

Variation in the Nutritional Value of Cereal Straw

Information from feeding experiments to compare the nutritive value of straws is scarce. Hence conclusions on the nutritive value, particularly digestibility, will be drawn from laboratory measurements despite the difficulties of predicting nutritive value from such measurements.

The digestibility of straw or stubble from wheat is usually, but not always, lower than for barley or oats (Table 2). In most studies the range in digestibility within species was large, and there was overlap in value from different species. Similar data are available on cell wall concentration and composition, crude protein and mineral levels in many of these studies. The data demonstrate that there is variability in digestibility due to genetic (species, cultivar) and environmental (location, year, season) factors, to management practices (time and method of sowing and harvesting) and to laboratory procedures used to estimate digestibility. In most experiments straw digestibility has not been strongly or consistently related to agronomic characteristics. However, in some work, plant height has been related to the proportions of leaf blades and stem components, suggesting that this characteristic may be a useful indicator. In a survey of straws in SW Western Australia, Purser (1982) observed that DM digestibility of straw declined from 45% – 30% with increasing rainfall and longer growing season. Wales *et al.* (1990) observed digestibility of a single cultivar of wheat straw to range from 30 – 47% at different locations within the one season. Location can have a larger effect than cultivar on digestibility of barley straw (Capper *et al.* 1988). This is also apparent for differences between years (White *et al.* 1981; Orskov *et al.* 1990).

The major botanical fractions of wheat, barley and oat straws are leaves (blades and sheaths) and internodes, with nodes and chaff (flower head including loose husk) being minor components. The leaf blade is usually more digestible than the leaf sheath, which is more digestible than the stem (Table 3). There are also differences within stems, with digestibility of the internodes increasing from the bottom to the top of the stem. The digestibility of both the leaf and stem

Table 2 Digestibility (%) of residues from wheat, barley and oat crops. Values in parentheses are standard deviations or ranges (Doyle 1994).

Location	Parameter	Wheat	Barley	Oats	Reference
Australia	IVOMD	36(30-45)	45(40-46)	40(34-46)	Pearce *et al.*(1979)
	NBDMD	(38-46)		(45-47)	Aitchison (1988)
		(30-36)	(42-43)	(37-44)	Aitchison (1988)
		(41-47)	(45-51)	(37-49)	Aitchison (1988)
		(28-35)	(30-37)	(26-32)	Aitchison (1988)
Canada	IVOMD	37(34-39)	38(37-40)	40(37-43)	Kernan *et al.*(1979)
	NBOMD	36(30-41)	49(44-53)	54(48-58)	Colucci *et al.*(1992)
Germany	NBDMD	41(37-46)	42(34-54)	57(49-65)	Flackowsky *et al.*(1991)
Sweden	IVOMD	47(28-58)	48(32-61)	55(40-68)	Eriksson *et al.*(1982)
UK	IVDOMD	43(3.8)	46(4.6)		Adamson & Bastiman (1984)
	IVDMD	32(27-36)	34(31-38)		Jewell *et al.*(1986)
	NBDMD	37(35-40)	50(39-61)	49(44-52)	Tuah *et al.*(1986)
	IVOMD	43	44	49	Mason *et al.*(l988)
	NBDMD	44(39-48)		38(37-41)	Shand *et al.*(1988)
	IVDOMD	42(6.4)	43(5.5)	49(6.3)	Givens *et al.*(l989)
	NBDMD	44(35-56)	47(34-61)	43(37-52)	Orskov *et al.*(1990)
	IVDOMD	37	47	46	Moss *et al.*(1990)
USA	IVDMD	39(28-40)	45(33-52)	45(40-48)	White *et al.*(1981)

IVDMD and IVOMD = in vitro dry matter and organic matter digestibility measured by rumen fluid or enzyme assays.
IVDOMD = in vitro digestible organic matter in dry matter.
NBDMD and NBOMD = nylon bag dry matter and organic matter disappearance.

Table 3 Variation in in vitro organic matter digestibility (IVOMD) of fractions of 78 samples of mature wheat plants (Winugroho 1981).

Fraction	Mean	SD	Range
Husk	53	5.0	44-66
Rachis	43	4.1	34-52
Stem internode	27	2.8	21-35
Stem node	41	3.7	34-50
Leaf blade	68	4.1	58-77
Leaf sheath	53	3.9	45-63
Stem (internode + node)	29	2.3	24-36
Leaf (blade + sheath)	59	3.7	51-68
Whole plant, excluding grain	43	2.9	36-50

component can vary with environmental conditions under which the straw is grown (Winugroho 1981). The decline in digestibility with increasing rainfall observed by Purser (1982) was associated with similar declines in the digestibility of the leaf and stem fractions.

Although it is possible to draw general conclusions that straws high in leaf are likely to be more digestible than those high in stem, it is not currently possible to predict the consequences of the complex factors associated with genotype, environment and their interactions on digestibility and nutritive value of straws and stubbles.

Making Best Use of Abundant Low Quality Crop Residue and Roughage

Maximum intake and production

A common situation is to have roughage available as a large amount of stubble or dead mature pasture, but of quality too low for target nutrient intake and animal production. Such low quality roughage can often be used most effectively by animal management procedures directed towards achieving maximum roughage intake, and/or by providing essential nutrients that promote efficient rumen digestion as well as efficient utilisation of absorbed nutrients by the animal. Advantages are that feed is utilised before it declines in quality or disappears due to trampling, decay, leaching and fire. Nutrients are in effect stored as body fat (or at submaintenance, rate of loss of body fat reserves is reduced), and the need for crisis management or high level feeding is delayed. A major disadvantage is that to achieve maximum intake and higher productivity per animal it will usually be necessary to accept a reduced efficiency of utilisation of low quality roughages. Also metabolic inefficiencies are involved in the deposition and subsequent mobilisation of body fat.

Factors limiting intake in pens

The primary determinant of ME intake of temperate pastures of low quality is usually assumed to be the digestibility. As digestibility increases from 40% – 55%, ME intake is likely to double, partly due to the increase in digestion but more importantly due to increased intake. Tropical grasses differ in that voluntary intake is also strongly influenced by the leaf/stem ratio. Intake of leaf is often 30 – 50% greater than stem material of the equivalent digestibility (Laredo and Minson 1973; Poppi *et al.* 1980). Presumably this is because the stem tissue has greater structural strength, and this limits particulate matter breakdown and passage from the rumen. Temperate pasture grass species usually have much smaller differences in structural strength, as measured by grinding energy, between the leaf and stem components.

There is appreciable evidence that voluntary intake of straws of temperate cereals such as wheat and barley is, like tropical grasses, influenced more by the leaf content of the ingested material than by digestibility *per se.* This is consistent with the observation that stem of straws is much thicker and tougher than that of most temperate pasture species. These effects are likely to be accentuated for crop residues from sorghum or maize, since the stem material of these crop species is larger and thicker than that of wheat or barley. It is often observed that ruminants, and sheep in particular, will consume little stem of sorghum or maize. Hence, although digestibility may be a fairly good determinant of ME intake of low quality temperate pastures, it is less useful for crop residues.

Voluntary intake increases with the proportion of leaf blade and leaf sheath for wheat straw (Wales *et al.* 1990) and barley straw (Capper *et al.* 1986; Rafiq *et al.* 1995) fed to sheep, and for rice straws fed to cattle (Winugroho and Sutardi 1987; Wanapat and Kongpiroon 1988). In these experiments differences between leaf and stem components in the resistance to physical breakdown (as measured by grinding energy) and in digestibility have often been confounded, since leaf is usually both higher in digestibility and lower in grinding energy than stem. However, two lines of evidence suggest that differences in the resistance to physical breakdown and therefore leaf content is the more important factor. Firstly, Asian rice straw is unusual in that digestibility of leaf is often similar to or less than that of stem, but voluntary intake of such rice straw is positively related to leaf content. Secondly, a wide range in voluntary intakes of barley straw by sheep was apparently related to straw characteristics such as leaf content rather than to digestibility (Capper 1988; Capper *et al.* 1989).

The degree of selection of straw components can also markedly affect intake. For example, when the proportion of barley straw refused by sheep in pens was increased from 20% – 75%, voluntary intake of straw was increased by 57% and ME intake by 92% (Wahed *et al.* 1990). It has also been shown that as the opportunity for selection of barley straw by sheep was increased, more leaf blade and less stem was consumed. Sheep tended to select against, rather than for, leaf sheath (Bhargava *et al.* 1988). We know of no equivalent data on the ability of cattle to select the components of fine–stemmed straws such as wheat or barley. The lesser ability of cattle than of sheep to select pasture components suggests that less selection would also occur with the cereal straws. Cattle fed in pens on a coarse-stemmed straw, finger millet *Eleusine coracana* increased voluntary intake of straw by 33% and ME intake by 52% as straw refusals increased from 15% – 43%, but no further selection occurred with higher levels of refusals (Rao *et al.* 1994).

Despite the importance of morphological composition, when straws are fed alone the content of an essential nutrient(s) may be more important than leaf content or digestibility in influencing intake. For example, Herbert *et al.* (1994) observed a close correlation between intake by sheep and the N content of barley straws when fed without a nitrogen supplement, but no relationship when the straws were fed with a nitrogen supplement. Under the conditions of this experiment neither leaf content nor digestibility characteristics were important factors determining intake.

Factors limiting intake of sheep and cattle grazing stubbles

Ruminants grazing stubbles will obviously have far greater opportunity than animals in pens to select components of the crop residue. We are not aware of any direct measurements of the degree of selection of leaf components in sheep or cattle grazing stubbles. However, shortly after harvest stubbles often contain appreciable amounts of spilt grain, and may also contain green herbage as weed growth.

The very large differences in selection and intake between grazing animals and penned animals are demonstrated in the study of May and Barker (1984). Cattle grazing barley stubble gained 0.85kg/d, or with the addition of an NPN based supplement 1.0kg/d. However, animals in pens fed the same barley stubble, but baled, lost 0.34kg/d in the absence of supplement and gained 0.19kg/d with the addition of the NPN based supplement. This experiment demonstrates the large difference between animals grazing stubble or fed nominally the same roughage in pens; both the level of production and the response to supplement were markedly affected. It is therefore necessary to examine results from grazing experiments to understand the likely responses of sheep and cattle grazing cereal stubble.

Extensive information on the intake and productivity of sheep and cattle grazing wheat, barley and oat stubbles in the southern Australian environment is provided by the series of experiments of J.B. Coombe, J.G. Mulholland and colleagues. One major conclusion was that both sheep and cattle, but particularly sheep, have the capacity to select intensively for spilt grain and for any green herbage present in the stubble. Most of the green herbage was due to growth of broad–leaf plants following storms before or during the grazing period. Availability as low as 40kg/ha of green material resulted in a diet containing more than 80% green material, and the digestibility of the selected diet was usually 20–25 percentage units higher than the average of the plant material on offer. Within the range 40–500kg green DM/ha, ME intake was well correlated with the availability of green plant material. Later comparisons between sheep and cattle showed that cattle are less able than sheep to select green material in the stubble, but even when green DM/ha ranged from 240–500kg/ha, cattle were able to select a diet containing 45% green material and 18% higher in digestibility than the total plant material on offer (Table 4).

Table 4 The proportion of green leaf and the digestibility of material present in stubble, and the porportions of each of these ingested by sheep or cattle grazing the stubble. Calculated from results of Mulholland *et al.* (1977).

Measurement	Green leaf (%)	Digestibility (%)
Stubble on offer	14	34
Ingested by cattle	64	51
Ingested by sheep	93	67

In vitro digestibility of stubble and samples of the material eaten obtained from oesophageally–fistulated sheep or cattle.

The degree of selection for green plant material by both sheep and cattle was much greater in these stubbles than has been reported for temperature pastures. Differences in sward structure and the spatial arrangement for morphological components of cereal crop residue and green herbage in the stubbles compared with temperate pasture may have enhanced selection of green herbages. However, the use of different methods to estimate green plant material present makes it difficult to compare between experiments. For example quadrats cut with a shearing handpiece as done in the above experiments will give lower estimate of green herbage availability than quadrats cut with a scalpel to ground level (P.T. Doyle, unpublished results).

In the above experiments the availability of green plant material was largely a consequence of summer storms. During drought such storms are likely to be infrequent, and sheep and cattle grazing stubbles will usually only have the opportunity to select from dead plant material. Coombe and Mulholland (1983; 1988; 1989) examined selection by sheep and cattle grazing stubbles where green plant material was eliminated as far as possible with herbicides. Sheep were still able to select a diet which was 8% digestibility units and 0.3% N higher than the plant material on offer. Similar selection was observed in cattle. This indicates that both sheep and cattle have the ability to select the stubble components of appreciably higher nutritional value than the average of plant material on offer.

There is also evidence of selection by both sheep and cattle of the leaf components of stubbles from studies of disappearance of various plant components. Such data are less satisfactory than those derived directly, because leaf in particular will be lost by shattering during grazing. Nevertheless these measurements suggest that sheep preferentially consumed spilt grain, leaf and glumes (Table 5). Measurements have been reported for cattle grazing grain sorghum stubble under North American conditions (Ward *et al.* 1979). On average over two years, 44% of the stubble disappeared during a three–month grazing period, but only 19% from ungrazed enclosures. The proportions of the morphological components suggested that the cattle selected strongly for leaf and against the stem component, with leaf comprising 76% of the ingested stubble. Similar observations for cattle grazing maize crop residues indicated an order of selection of grain, leaves and husks, stalks and then cobs (Lamm and Ward 1981).

Liveweight change of sheep and cattle grazing stubbles

Liveweight (LW) change reported for animals grazing stubbles has varied widely between trials. In general, performance of cattle at moderate stocking rates has usually been between maintenance and moderate growth (0.9kg/d) for the first 6–8 weeks of grazing, presumably associated with ingestion of spilt grain, weeds, and the nutritionally higher quality components of the stubble (Table 6). However, when grazing was

Table 5 Quantities of wheat stubble components before (January) and after (April) grazing by sheep at Merredin, WA in 1970 (H.E. Fels, unpublished results).

Component	January	April	Disappearance	
	kg/ha	(kg/ha)	(kg/ha)	Percent#
Spilt grain	46	1	45	98
Leaf	388	125	263	68
Stem	424	328	96	23
Flower stalks	40	17	23	58
Glumes (husks)	130	33	97	75
Total	1028	504	524	51

Percentage disappearance between January and April.

Table 6 Liveweight change of cattle grazing stubble without supplement or with various supplements based on NPN/S, and with green weed growth or nominally weed–free.

Expt	Stubble type	Supp	Duration (weeks)	LW change (kg/d)	Reference
1	Barley, weed-free	Nil	0-8	+0.9	A
		S1	0-8	+1.0	A
2	Oat	Nil	0-8	+0.5	B
3	Wheat, weedy	Nil	0-11	+0.5	C
	Wheat, weed-free	Nil	0-11	+0.1	C
	Oats, weedy	Nil	0-11	+0.6	C
	Oats, weed-free	Nil	0-11	-0.1	C
4	Oat, weed-free	Nil	0-6	+0.6	D
		S2	0-6	+0.4	D
		S3	0-6	+0.2	D
		Nil	6-12	-1.6	D
		S2	6-12	-0.5	D
		S3	6-12	-0.5	D
5	Wheat	Nil	0-11	+0.1	D
		S2	0-11	+0.1	D
		S3	0-11	+0.1	D
		S4	0-11	+0.3	D
		Nil	11-15	-1.4	D
		S2	11-15	-1.1	D
		S3	11-15	-1.4	D
		S4	11-15	-1.2	D

Supplements: S1, biuret + grain + P.
S2, molasses (300 g/d) + urea (3 g/d) + minerals
S3, molasses (300 g/d) + urea (60 g/d) + minerals
S4, urea/molasses block

References: A, May & Barker 1984; B, Smith & Warren 1986; C, Coombe & Mulholland 1988; D, Coombe & Mulholland 1989.

continued for longer periods in stubbles with little or no weed, apparent LW losses could be severe (1.3 – 1.6kg/d). ME content of the ingested diet was also low during this period of severe LW loss (*in vitro* DM digestibility 38%; Coombe and Mulholland 1989).

Wide variation in LW change has also been observed for sheep grazing stubbles (Table 7). At moderate stocking rates and with appreciable amounts of spilt grain or green plant material present, maintenance or slow growth (up to 1.4kg/month) have usually been observed. With adult sheep grazed at high stocking rates (30 sheep/ha) on stubble of low weed content, LW change has tended to range from maintenance to LW losses of up to 2.5kg/month. As with

Table 7 Liveweight change of sheep grazing cereal stubble without supplements or with various supplements based on NPN/S, and with green weed growth or nominally weed-free.

Expt	Type of sheep	Stubble type, stocking rate	Duration (weeks)	LW change (kg/month) Nil supp	Plus upp	Reference
1	W	Wheat (7.5/ha)	6	-5.6	-3.8 (S1)	A
2	A	Wheat (5/ha)	14	-2.6	-2.1 (S4)	B
3	H	Oat	14	+0.2		C
		Barley	14	+0.8		C
		Wheat	14	+0.2		C
		High stocking rate (26/ha)	14	+0.0		C
		Low stocking rate (13/ha)	14	+1.1		C
4	H	Oat	14	-0.3		C
		Barley	14	+0.6		C
		Wheat	14	+0.5		C
		High stocking rate (30/ha)	14	-0.9		C
		Low stocking rate (15/ha)	14	+1.4		C
5	H	Oat	11	-0.2		C
		Barley	11	-0.5		C
		Wheat	11	-1.2		C
		High stocking rate (30/ha)	11	-1.9		C
		Low stocking rate (15/ha)	11	+0,7		C
		Weedy	11	0.0		C
		Weed-free	11	-1.2		C
6	H	Oat, high stocking rate (30/ha)	11	-2.2	-1.1 (S5)	C
		Oat, low stocking rate (15/ha)	11	+0.1	+0.9 (S5)	C
7	H	Oats, high stocking rate (23/ha)	14	+0.3		D
		Oats, low stocking rate (11/ha)	14	-2.9		D
8	H	Wheat, weed-free (7/ha)	15	-1.3	-0.2 (S2)	E
				-1.3	-0.5 (S3)	E
				-1.3	-0.2 (S4)	E
9	A	Wheat (5/ha)	12	-2.5	-0.9 (S4)	F
10	A	Oat, weedy (20/ha)	11	+0.1	+0.2 (S2)	G
				+0.1	+1.1 (S3)	G
				+0.1	+2.1 (S4)	G
10	A	Oat, weed-free (20/ha)	11	-2.3	-0.7 (S2)	G
				-2.3	-0.2 (S3)	G
				-2.3	-1.5 (S4)	G
11	W	Wheat, pre-grazed (10/ha)	5	-1.4		H
12	H	Wheat, pre-grazed (10/ha)	14	-0.9		I
13	H	Wheat, pre-grazed (10/ha)	5	-2.9		J

Type of sheep: W, weaner; H, hogget; A, adult

Supplements: S1, molasses-urea sprayed on to pasture; S2, molasses (50 g/d) + urea (0.5 g/d) + minerals; S3, molasses (50g/d) + urea (10 g/d) + minerals; S4, urea/molasses blocks of various formulations; S5, urea + grain.

References: A, Coombe & Tribe 1962; B, Messenger *et al.* 1971; C, Mulholland *et al.* 1976a; D, Mulholland *et al.* 1976b; E, Mulholland & Coombe 1979; F, Butler 1981; G, Coombe & Mullholland 1983; H, Rowe & Ferguson 1986; I, Rowe *et al.* 1989; J, Morcombe & Ferguson 1990.

cattle, LW loss has tended to increase late in the grazing period. Severe LW loss (1.0 to 5.6kg/month) occurred where weaner sheep grazed wheat stubble which had been grazed by other sheep following harvest (Rowe and Ferguson 1986; Rowe *et al.* 1989; Morcombe and Ferguson 1990). These rates of LW loss were presumably associated with the higher nutritional requirements and lower capacity of young sheep to consume low quality roughage, to the pre–grazing which removed spilt grain and weed, and also perhaps with absence of, or limited weed growth, during the experiments.

A difficulty with all of these measurements is that LW change in sheep grazing stubbles can be misleading as soil ingestion can be considerable. Condition scoring may be a useful complement to weighing when monitoring animal performance.

The data presented in Tables 6 and 7 are for stock grazing cereal stubbles. For sheep grazing lupin or pea stubbles LW gains early in the grazing period can be higher than for cereal stubbles. However, the feeding value of these stubbles is depleted more rapidly than that of cereal stubbles.

Strategies for Most Effective Utilisation of Stubbles

As discussed above, a characteristic of stubble grazing is that LW tends to be maintained, or lost at only a slow rate while green herbage is available in the stubble, or in weed–free stubbles for the first 2–3 months of grazing. Severe LW losses thereafter presumably coincide with the animals no longer being able to select high digestibility components. Even with high stocking rates (*e.g.* 30 sheep/ha), only a small proportion of the total stubble DM on offer will be consumed during a 3–4 month grazing period.

One strategy to increase the efficiency of utilising grazed stubble would be to minimise loss of leaf components by shattering, trampling and decay, and to maximise their ingestion. This could be achieved by high stocking rates and grazing systems which limit the area available at any one time (*e.g.* a strip grazing approach).

A second strategy would be to match the stubble quality after various grazing intervals to animal requirements. This might be done by a 'leader and follower' grazing system, with the followers being those animal groups best able to tolerate substantial LW loss. However, modified grazing systems such as these will involve greater infrastructure costs for fences and water. Issues which would have to be addressed in setting up such systems would include stocking rates, acceptable LW loss for various groups of animals, which supplements if any should be used, and timeliness.

The low utilisation of total crop residue dry matter by grazing animals is because dry matter disappearance due to decomposition and trampling usually occurs at a much greater rate than intake by the animals, and because the animals will not consume much of the stem material.

A strategy to greatly increase the amount of crop residue that is utilised to bale stubble and feed it as needed. This also avoids problems associated with timeliness of ground preparation for the next crop, and it may also be possible to graze the aftermath after baling. This strategy is likely to be particularly important for farms with a shortage of roughage. However, the reduced selection when stock are offered baled straw rather than grazing stubble means that supplementation of the straw will usually be essential and there may be insufficient ground cover to provide protection against soil erosion. A refinement of this strategy would be to modify the combine harvester to fractionate the straw into the leaf–rich and stem-rich components, and to bale the leaf–rich fraction. Issues which would have to be addressed when setting up such a system would include the cost per unit of ME of the straw, acceptable LW loss of the animals, and type and level of supplements to be used.

Another strategy would be to use conventional grazing systems and to provide supplements containing essential nutrients and additional ME. Supplements based on cereal grain or protein meals may often be the preferred option. However since these are discussed by other papers in this workshop (Rowe *et al.* 1995; Hennessy *et al.* 1995), the present discussion will be limited to supplements which provide essential nutrients for rumen digestion.

Supplementation with Nutrients for Rumen Microbial Digestion of Roughage

Delivery systems to supply NPN/S supplements

The common sources of NPN (non–protein nitrogen) and S (sulphur) are fertiliser grades of urea, sulphate of ammonia, and elemental sulphur. Much of northern Australia is also deficient in phosphorus, and common sources are feed grade calcium phosphates. Molasses has a high sulphur content.

The most common methods of providing NPN/S supplements have been by molasses/urea roller drums (Lindsay & Laing 1995) or by high-urea dry licks or blocks (*e.g.* Uramol). In northern Australia roller drums systems are now seldom used because of the high costs for the roller drum units, and for machinery and labour. Dry licks are tending to replace blocks because of their lower cost per unit of N or P. Dry licks are loose mixes of ingredients such as salt, urea, calcium phosphates, sulphate of ammonia, protein meal, grain and molasses. Urea is included at 30 – 40% to provide N, sulphate of ammonia to provide S as well as N, and calcium phosphates at 5 – 100% to provide P; the other ingredients are principally to make the supplement acceptable to the cattle.

Water medication, by adding soluble N or P supplements into the water supply, has two major advantages. Firstly, only the essential nutrients (as urea N and/or P) need be supplied. Secondly, if the only water available is medicated all animals must consume their supplement, and presumably the variation among animals in supplement intake is low. However, despite these advantages, and attempts over several decades to develop the technology, there has been little adoption by industry. Many of the reasons for this lack of adoption appear to be problems of engineering rather than of animal nutrition.

The two common options for medicating water are by:

- Automatic dispenser machines which add supplements to the water supply line to troughs; and

- Mechanically mixing supplements into the water in supply tanks.

Many dispenser machines have been developed, but most are not sufficiently reliable under extensive conditions. Two machines which have gained some acceptance by industry are the 'Dositron' and the 'Norprim' both of which dispense concentrated solutions. Problems can occur with mixing urea into supply tanks with the settling out in the bottom of the tank of a cold, high density layer of water containing a high concentration of urea; this solution of concentrated urea is likely to then enter the supply line to the trough. Problems can be associated with water quality. Water containing high concentrations of calcium or magnesium salts can cause precipitation of calcium or magnesium phosphates in the supply tank and/or the water supply line, effectively removing the P from the water and blocking the supply lines. Where the water supply is alkaline, urea supplement can be hydrolysed and the ammonia lost by volatilisation, effectively removing most of the N supplement from the water. Algal growth in the supply tank can also cause problems. Application of water medication is also limited by the needs for controlled and centralised water supplies, and for skilled maintenance of the system.

Nutritional problems with water medication are the high cost of P sources such sodium monophosphate suitable for water medication and, the possibility of urea toxicity. Also little information is available on whether urea N ingested in the water is used with similar efficiency to urea N ingested in supplements (McLennan *et al.* 1991).

Liveweight and reproduction responses

Responses by sheep and cattle to supplements of NPN/S alone, with other minerals, or with small amounts of grain or molasses for cereal straws and other low quality roughages have been examined in numerous experiments.

Many pen experiments with both sheep and cattle have shown large increases in intake of roughage and of ME, and alleviation of LW loss, in response to NPN/S supplements for cereal straws or low quality roughages. These responses have often been related to a dietary deficiency of rumen degradable nitrogen, and rumen ammonia concentrations which we would expect to be too low to support maximum microbial digestion of low quality roughage.

A number of researchers with sheep and cattle grazing cereal stubbles or senesced pastures in southern Australia have reported small responses, or sometimes no response, to NPN/S/molasses/grain supplements, and benefits were lost during subsequent compensatory growth (Table 6 and 7). Based on this type of information many workers have concluded that NPN–based supplements are of little value (Messenger *et al.* 1971; Mulholland & Coombe 1979; Coombe & Mulholland 1989). However, in the experiments summarised in Table 7, on average LW loss of unsupplemented sheep was 1.4kg/month. The reduction in LW loss due to the NPN supplements was on average 1.2kg/month, and ranged from 0.5 to 2.1kg/month. Therefore we conclude that although the effect of NPN/S supplements is usually small, they do have an important role in alleviating the rate of LW loss and allowing longer utilisation of stubbles and senesced pastures.

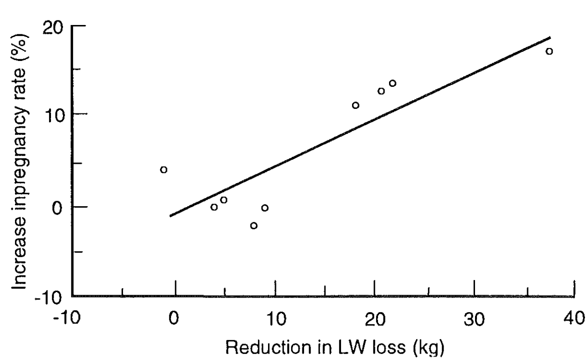
Comprehensive studies with young Bos indicus cross cattle grazing speargrass pastures during the dry season in northern Australia have clearly shown the benefits of NPN/S supplements in this environment (Table 8). Over 12 experiments the reduction in LW loss averaged 18kg, and ranged from no effect in benign dry seasons up to 36kg during harsh dry seasons. The alleviation of LW loss due to NPN/S supplements can be even greater in breeder cows, and is sufficient to drastically reduce breeder mortality; industry surveys suggest reductions from 12 – 15% to 3 – 6% per annum. There is also clear evidence of increases in reproductive rates of cattle (Figure 1) and sheep (Stephenson *et al.* 1981). Use of dry lick supplements high in NPN/S/P for breeders and weaners has become routine for much of the northern cattle industry during the last decade. Supplements based on molasses, grain or protein meals give much larger responses, but are too expensive to be used routinely for breeders.

Table 8 Liveweight change responses of young Bos indicus cross cattle grazing dry season speargrass pastures to supplements providing principally urea N and inorganic S.

Year	Months of supplement	LW change (kg)			Expt
		No supplement	Plus supplement	Change due to supplement	
Molasses-urea roller drums supplement					
1970	3	-4	+21	+25	A
1970	6	-26	+10	+36	B
1971	6	-4	+16	+20	B
1972	7	-51	-16	+35	B
1971	7	+4	+26	+22	C
1972	7	-14	+2	+16	C
1973	6	+13	+31	+18	C
1974	5	+43	+54	+11	C
Urea-salt dry lick supplement					
1975	5	-4	-3	+1	D
1976	6	-13	0	+13	D
1977	8	+45	+56	+11	D
1978	6	-2	+9	+11	D

Experiments: A, Winks *et al.* 1972; B and C, Winks *et al* .1979; D, McLennan et al 1981.

Figure 1 The relationship between the reduction in LW loss of breeders during the dry season due to NPN based dry lick supplements, and the increase in pregnancy rate from mating during the subsequent wet season. Source of data: Holroyd *et al.* 1983; 1988; R.M. Dixon, M.J. D'Occhino and G. Fordyce unpublished results.



Reasons for Variable Responses to NPN/S Supplements

Selection by animals under grazing conditions

The abilities of both sheep and cattle to select spilt grain, green herbage and the higher digestibility components of stubble have been discussed above. With such selection the diet ingested may be quite high in quality and not be deficient in N and S for rumen fementation. There will usually be no opportunity for breeders in the northern Australia environment to select green material during the later dry season, and senesced native pastures in the semi–arid tropics are of very low quality.

Interactions between straw characteristics and supplements

Two experiments have shown the importance of the quality and morphological components of straw ingested on responses to supplements of NPN/S, protein meal or cereal grain. Doyle and Panday (1990) examined the responses to urea supplement in sheep consuming two wheat straws which differed widely in leaf content, IVOMD and intake when fed alone. Intake of the high leaf, high intake straw was increased by 26% by supplementary urea, but that of the low leaf, low intake straw was not changed. In another experiment (Rafiq *et al.* 1995) sheep were fed diets consisting predominantly of separated barley straw leaf or stem and various supplements. Supplements of NPN/S resulted in a 27% increase in DM intake, a 41% increase in ME intake, and alleviation of LW loss with the high leaf diets, but had no effect on the stem diet. Similarly, a fishmeal supplement increased intake of leaf roughage, but not of stem roughage. These two experiments suggest that when animals can select a diet consisting mainly of leaf, large responses are likely to occur to NPN/S supplements, but that when animals have to select a diet consisting mainly of stem responses to NPN/S are unlikely. The latter experiment also suggests that with diets based on cereal straw leaf, the constraints to intake and growth will be associated with supply and balance of nutrients for both the rumen and for the animal. However with diets containing a large proportion of stem material, particle breakdown and passage is likely to be the first limiting factor to intake.

Supplement delivery systems

Many of the poor responses by grazing animals to NPN/S supplements are probably associated with high variability in supplement intake among individual animals in the mob. Measurements of variation among individual animals in intake of dry licks or blocks indicate large variation (CoV usually exceeding 50%,) and there may be a considerable proportion of animals which do not consume supplements at all during the early weeks and months of exposure to the supplements. This is also the period when NPN/S supplements are likely to be most effective. Furthermore the proportion of non-eaters and the variation in supplement intake is likely to be much greater for low palatability dry licks or blocks than for more palatable concentrates (Wheeler *et al.* 1980; Table 9). However, even following adaptation of animals to a delivery system providing palatable supplements, the variation of supplement intake is likely to be substantial (*e.g.* CoV of at least 20%). Unequal intakes by individual animals will be much more important for NPN/S supplements than for concentrate supplements because the responses to the NPN/S only occur up to a threshold level meeting rumen microbial requirements, with no response thereafter. The management strategies to alleviate this problem are likely to be by training of animals when they are young to accept supplements, and by choosing supplements associated with low variability.

An additional reason for poor responses to NPN/S supplements containing urea as the NPN source is poor synchrony of supply of the N substrate with slow digestion of fibrous components. This may explain better responses observed in some experiments with high–urea lick blocks available at all times, compared with molasses/urea liquid supplements which were only available to the animals for about 2 days of each 4 day feeding cycle. Synchrony of supply may be improved by providing the NPN/S with fermentable substrate to allow rapid microbial growth, which is followed by slow release of N with turnover of microorganisms.

The Value of NPN/S Supplements

Much of the difference in perception of the value of NPN/S supplements (*e.g.* between Southern and Northern Australia) follows from differences between environments and planned levels of production. For example in the semi–arid tropics under-nutrition during the prolonged (5 – 10 month) dry season results in average breeder mortality of about 10% per annum and branding rate of 60%. The principal value of NPN/S supplements in the northern cattle industry is to delay the need for high-cost options or, where these cannot

Table 9 Variation in intake of supplements among individual animals with the mob, and number of non-eaters of supplement in the mob. Bos indicus cross heifers (18 months of age) were fed restricted amounts of cottonseed meal twice weekly, or had ad libitum access to molasses containing 8% urea (M8U), dry lick based on salt and urea, or molasses based lick blocks (R.M. Dixon and J.C. Petherick, unpublished results).

Supplement	Coefficient of variation within mob (%)	Fraction of non–eaters of supplement
Cottonseed meal	27	0/40
Molasses/urea (M8U)	31	0/40
Dry lick	69	1/40
Blocks	82	5/40

be implemented, to reduce mortality of susceptible animals (breeders and weaners). This is demonstrated in Figure 2.

By late in the dry season breeder cows are often approaching the critical LW and body condition for survival. A reduction in LW loss of 20 – 30kg during the dry season (*e.g.* to November), means that crisis feeding (or other costly management strategies such as sale of cattle in poor body condition) is not required for an additional 4 – 8 weeks. Hence the value of the NPN/S supplements for a specific property is influenced principally by the costs of crisis feeding, the probabilities of the seasonal break occurring in various months, and the changes in mortality and the level of production due to the NPN/S supplements. However, the efficacy of a dry season supplementation strategy has to be balanced against other management strategies such as calving times, weaning, stocking rate and wet season supplementation to increase body reserves before the dry season commences.

In southern Australia target production levels are much higher, drought periods are usually much shorter, and greater flexibility with alternative management strategies (such as sale, agistment, production supplementation or complete hand feeding), means that NPN/S supplements (to alleviate LW loss) are less important in drought management. Nevertheless we suggest that NPN/S supplements do have an important role in many southern situations where sheep and cattle are fed crop residues to reduce rate of LW loss, relieve grazing pressure on other pasture areas, and delay the necessity to implement alternative nutritional or management strategies.

Conclusions

There is wide variation in voluntary intake, ingestion of nutrients and performance of stock depending primarily on crop residues or senesced pasture. Although we probably have a fairly good understanding of causes of this variation, we currently have a poor ability to predict intake of ME and other nutrients in practical situations. Producers will have to still depend to a large extent on monitoring of stock performance coupled with ongoing adjustment of management and supplements to achieve desired goals of productivity.

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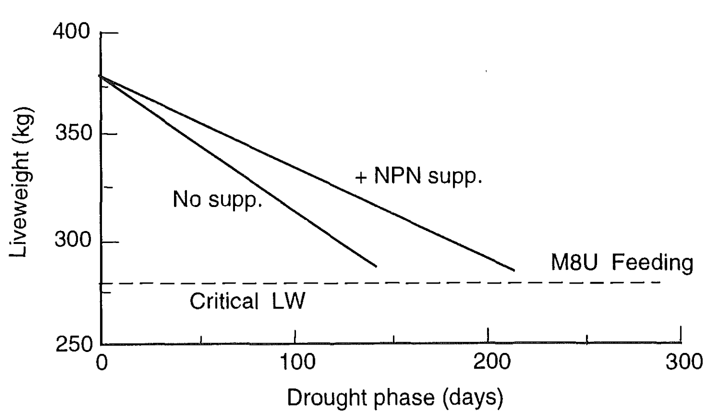
Figure 2 A diagrammatic representation of the consequences of NPN supplements fed during the dry season drought on liveweight loss by breeders. The NPN supplements delay the time when breeders approach the critical liveweight for survival, and when crisis feeding with M8U is needed to avoid high mortality rates.



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Pasture Management and Stocking Rate Policies

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Summary

Productive pastures are the most cost–effective source of feed for livestock, producing feed at a discounted cost of from $30/tonne down to $10/tonne if they persist for more than 3 years or 10 years respectively; this is far more economic than bought grain ($325/tonne) or hay ($160/tonne).

Many graziers have 'lost the plot' with their pastures by undervaluing their capacity to deliver quality feed at a low cost, provided that adequate inputs are applied to balance prior exploitative practices. Opportunities for increasing returns are also missed when the pasture base is in such poor condition that it barely grows when favourable conditions do occur.

Droughts are not new phenomena. Farmers need to be able to adjust to drought with flexible management and prudent tactical decisions in the face of risk. Valuable pasture plants are lost due to the dual stresses of drought and grazing. Drought management research on the Northern Tablelands of NSW has shown that perennial grasses, if grazed hard, can die even in commonly experienced dry periods, not just those drought periods which are extreme. More moderate grazing of grasses subjected to drought leads to greater energy reserves for regrowth and thereby greater survival. Hence, there is a need, during drought, to lessen grazing pressure on pastures if they are to survive and thereby protect prior investments and be capable of rapid growth when conditions improve.

Stocking rates can and should be adjusted, both property wide and in individual paddocks, as the need arises. Graziers should be aware that there is no optimum stocking rate—stocking pressure needs to be varied along with conditions. Yet, grazing pressure is one of the key determinants of pasture productivity, persistence, botanical composition and thereby animal productivity and profits.

A wide range of pasture management options are briefly outlined and the point is made that many of these need to be used in conjunction with each other if overall pasture management is to be successful.

For future sustainable systems, graziers need to embrace flexibility, diversification, an ability to capitalise on good times by developing their natural capital (including soil, pasture and animal capital) as well as financial capital, such as off–farm investments.

Livestock enterprises based on grazed pastures are long-term ventures. The benefits to be reaped from well managed pastures may not be immediately apparent but are substantial over the long–term. Some suggestions are given for how we might learn to drive these complex grazing systems by developing decision tools which are powerful and yet intuitive to use.

In terms of the reference framework for this workshop, long–term pastures are seen as a highly desirable feeding strategy for livestock in drought because:

- Animals harvest the feed themselves without the inefficiencies brought about by having to harvest, transport and store the feed;
- The cost per tonne of feed is dramatically lower than that of bought grain or hay;
- The potential for introducing pests, weeds or residues is minimised;
- Animal welfare considerations can be minimised by de-stocking before serious weight loss;
- Animals are able to select a diet superior to the gross herbage quality through selective grazing; and
- No government incentives are needed—merely an appreciation by the grazier of the cost effective nature of investments in productive and persistent pastures.

However, there is a need to understand 'whole' grazing systems if sustainability is to be attained. Future work

needs to identify ways in which farmer decision making in a risky environment can be improved.

Introduction

The very fact that the prime focus of this workshop is on feeding livestock with plants other than pastures shows just how much some have 'lost the plot'. I will attempt to show how cheaply pastures can feed our livestock without large expenditure on supplementary feeding and hence minimise some of the financial and environmental concerns which arise from feeding with expensive supplements.

By 'losing the plot' I mean we have had exploitative grazing industries in Australia for too long. We have largely been mining our land since European settlement —not only our rangelands, but also our higher rainfall zones. There has been severe overgrazing during a century of exploitative pastoralism. In spite of considerable inputs, management inefficiencies are still apparent.

After all the publications on sustainability, why haven't we got the answer? The problem might be one of spelling—if only our dictionaries could be modified to record the spelling as '$u$tainability'!

In addition to 'losing the plot' I believe that, in the higher rainfall zone of Australia, we have been witnessing numerous lost opportunities relating to the low production levels many now accept from their pastures, even in times of adequate rainfall. Making up for these lost opportunities will be dealt with later under a discussion of future strategies.

We have been asked to address our topics under three sections:

1 Biology and efficacy;

2 Farm management issues—economic and environmental sustainability; and

3 Policy considerations—incentives.

Below, I will argue that a productive pasture base is the most efficient source of feed for livestock, that linking economic and environmental considerations is essential to understanding the value of pastures and that the main incentive needed for graziers is not government handouts but rather coming to understand the value of productive pastures over the long–term. Pasture sustainability cannot be separated from financial viability or herd productivity, nor biology, nor efficacy, nor the environment, nor policy. For example, the government policy of introducing a superphosphate bounty in the 1950s and then removing it in 1974 had profound effects, firstly on the productivity of our pastures and secondly on their decline as outputs of animal products were no longer balanced by inputs. Because of previous investments in nutrients, graziers who stopped fertilizing would at first have seen few consequences, however, 20 years later, the consequences of declining inputs are seen in today's degraded pastures with their poor productivity. Graziers are motivated by profit, among other things (Figure 1).

Many graziers place too much emphasis on their animals and forget that their livelihood also depends on having an underlying healthy soil and pasture base on which to feed livestock economically, whilst protecting their resource base (Figure 2).

Recent assessments of pastures in NSW have shown that few pastures are still dominated by the species widely sown in the years between 1950 and 1970. Such degraded pastures typically produce small quantities of low quality feed. This situation has led graziers in the current drought to rely heavily on bought feed, the typical cost of which is shown in Table 1. Faced with such costs, it is a wonder that

Figure 1 A typical grazier?—motivated by profit as well as caring for his animals and land but not recognising sufficiently the value of his soil and plant natural capital.

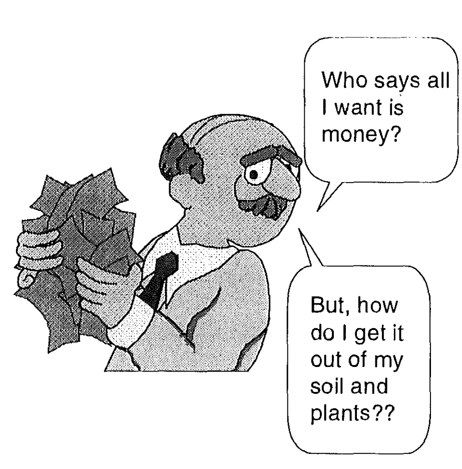


Figure 2 A hierarchy of layers of financial and natural capital indicating how profits from grazing depend on animal 'capital' which depends on plant 'capital' which, in turn, depends on soil 'capital' (adapted from Scott, 1990).

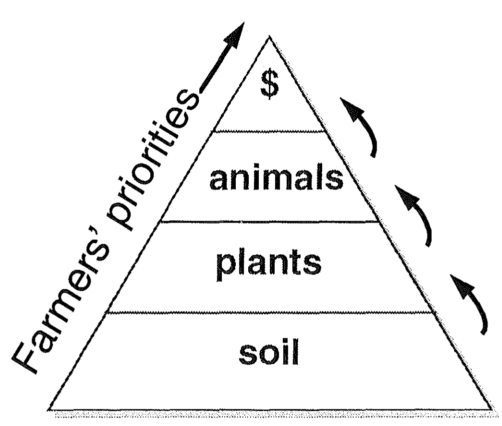


Table 1 Cost of various livestock feeds (from Armidale Rural Lands Protection Board News, April/May, 1995, p4).

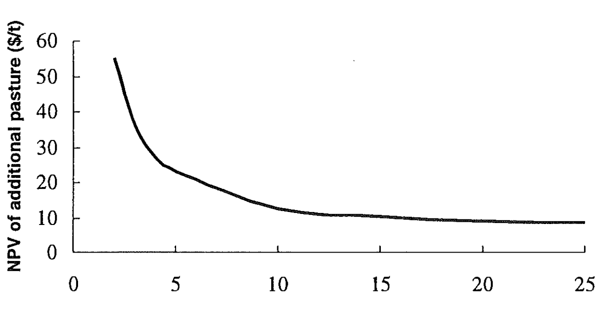
Feed	$/tonne
Wheat	$258
Oats	$280
Barley	$276
Corn	$255
Soybean meal	$325
Hay	$160

graziers now tolerate pastures with low production and low quality. There are some rare examples of pastures sown 30 years ago which are still in a productive state; these have typically received regular fertilizer applications which have balanced products removed from the pasture (*i.e.* wool and meat).

In the 'high rainfall' temperate zone (> 600 mm average annual rainfall), unfertilised native pasture growth is typically about 3 tonnes/ha/yr. With the addition of fertilizers to overcome soil nutrient deficiencies and with fertilizer–responsive species, this productivity can readily be lifted to 6–7 tonnes/ha/yr. In addition, the digestibility of the feed can be increased by 5-10% thus permitting greatly enhanced livestock performance.

The discounted cost of such additional feed depends to a large extent on the longevity of the pasture established before it needs re–sowing. Figure 3 shows the discounted cost per tonne of extra pasture produced following the establishment of a pasture at a cost of $200/ha with annual fertilizer additions thereafter. This graph shows that, if such a pasture lasts for 3 years or more, the cost of extra feed produced is less than $30/tonne; if it lasts 10 years, it can be as low as $10/tonne. These costs are very much lower than the cost of bought feed listed in Table 1 above. In drought seasons, stocking pressures have to be reduced to moderate rates if the valuable species are to persist beyond the drought and thus continue to be able to produce economic feed.

Figure 3 NPV (cost) of increased pasture produced over that of an unfertilised native pasture; calculations based on a sown pasture with annual fertilizer additions which persists from 2 to 25 years using real annual inflation rates as the discount factor.



Need to consider the whole problem

We need to consider the complex issues of real grazed systems if we are to seriously tackle the problems facing us in providing cost–effective feed for our animals over the long–term, and especially during drought. Farmers have to deal with the whole system. Williams (1994), a grazier, noted 45 factors as important in the management of his grazing enterprise (15 financial; 14 land management and 16 relating to cropping and stock activities). Just like farmers, research and extension messages must also take into account the complex of whole farm systems.

How Can We Learn More About Complex Systems?

To understand complex interactions between many factors, it is common to take a modelling approach which can incorporate the relationships between numerous levels each containing many factors—ultimately, such models may assist graziers in making difficult decisions. Much of the literature on modelling of relatively complete systems concentrates on managing in the rangelands where there are relatively few management opportunities.

In general, the treatment of 'whole' systems in the literature cannot yet be described as adequately encompassing all complexity of real farm systems. One of the most common weaknesses of the above models is their treatment of the biological aspects. If these are treated too simply, large errors can occur and the financial data derived from them will have little use. Nevertheless, Morley (1994a) notes that it is better to model with imperfect data if better quality data are not available. He agrees that having accurate model predictions would be preferable; however, he awaits ..."the development of such models with hope and optimism".

It is essential that components of any whole system model be realistic in their predictions. This applies to the biological components as much as the behavioural or economic. Some of the models which could be of use in supplying quality biological data include:

- SummerPack (Orsini, 1989) useful especially under Western Australian conditions to adjust stocking rate and calculate feed on offer and supplementation levels;
- GrazFeed (Moore *et al.* 1991) provides an excellent assessment of pasture availability, quality and supplementation for a wide range of classes of grazing sheep and cattle in the high rainfall, temperate zone, but is limited to a single time step; and
- GrassGro (Moore *et al.* 1991) incorporates GrazFeed and permits pasture to grow and respond according

to grazing intensity and climatic conditions; permits calculation of animal production and gross margins.

Some examples of the output from GrassGro show the number of months per year in which animal needs will be met by pasture growth (Figure 4).

Figure 5 shows how the model GrassGro can be used to analyse financial risks by comparing the average gross margins to the variability of those gross margins for a range of stocking rates and two feeding strategies.

Grazing systems

The identification of a logical means of deciding what stock to graze, on what pasture to graze them, and for how long, has been a quest of many for a long time. Some of the definitive early work on this topic in Australia was done by Moore, Barrie and Kipps (1954) who concluded that there were few differences in productivity between phalaris/subterranean clover pastures on the Southern Tablelands of New South Wales grazed continuously or in fixed rotations.

Recently in Australia, there has been a lot of publicity about new systems of grazing management which claim to provide a holistic answer to farmers' problems. These systems have been promoted for many years in other countries such as South Africa, USA and Canada and one can find a number of reports of experiences with them in the literature. The claims made for time–control or cell grazing have never been substantiated by facts and some published reports provide refutation of several claims made for these systems. Indeed, in a seminar in Armidale in December 1994, Savory himself rejected cell grazing, stating that it didn't work.

In Canada, short duration or time-control grazing was investigated, finding that "the hypothesis that animal impact would improve range condition was rejected. Rather, such impact ... resulted in retrogression of the grasslands". The "reduction of range condition ... (was) associated with less soil moisture and increased soil bulk densities indicating reduced infiltration rates." "The evidence indicates that time–controlled grazing, with a high herd density in a short duration grazing system, will not negate the effects of high utilisation." (Dormaar *et al.* 1989).

Nevertheless, neither continuous nor any fixed rotational system of grazing will provide a robust sustainable system. Flexible grazing systems which take into account climatic and seasonal factors, stage of growth of pastures, botanical composition, condition of animals, soil conditions, and economics are still the goal of many. The complexity of deriving an optimal solution to the problem is still an obstacle and is probably beyond conventional field experimentation. This means that, ultimately, computer aids may be needed to assist in such complex decision making.

Figure 4 Simulated monthly above–ground pasture growth and herbage intake, both in kg/ha/day, at 16 wethers/ha near Canberra in years where rainfall was that expected in the worst 20% of years (20 percentile) and the highest 20% of years (80 percentile) (Moore *et al.* 1994). These graphs readily show the months when enough feed is grown to match animal needs.

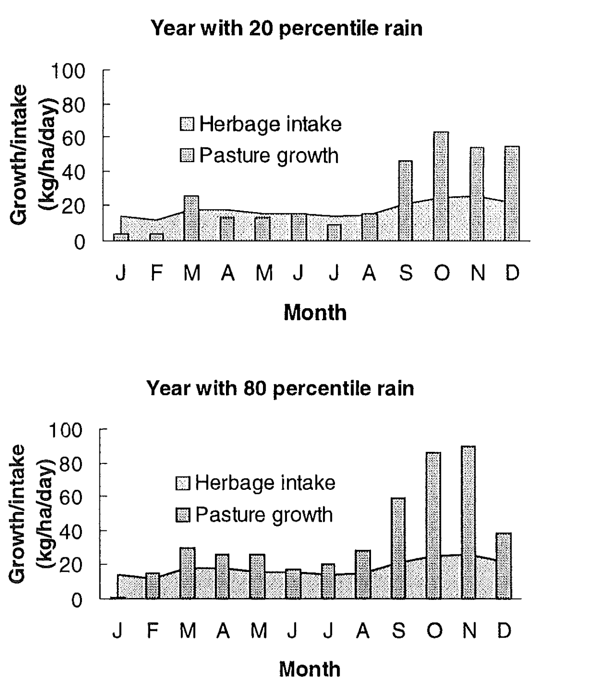
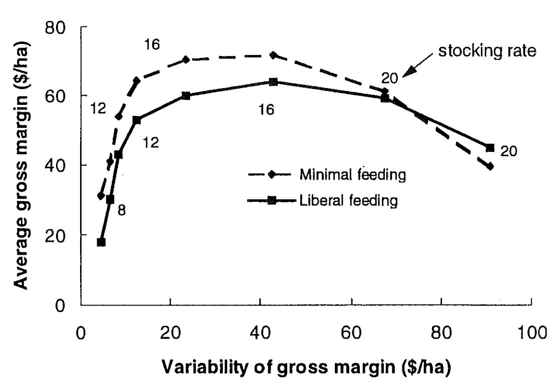


Figure 5 Rewards (gross margin) and risks (variability of gross margin) associated with two feeding policies and a range of stocking rates, in wethers/ha, shown as points on the graph, for a wether enterprise near Canberra (Moore *et al.* 1994).



Loss of valuable species

It is well known that valuable pasture plants are lost due to the dual stresses of drought and grazing. Whilst legumes tend to play an opportunistic role in perennial pastures (Sheath and Hodgson, 1989), grasses are relied on as the more drought resistant component and thus a more persistent backbone for stable, productive pastures. Hence, the perennial grasses must not be sacrificed because of short–term desperation.

In the traprock region of Queensland, the loss of valuable native species during the severe drought of 1965 resulted in less soil cover (15% down to 8%) (Clarkson and Lee, 1988). Even 12 months after the drought ended, there was no recovery of botanical composition, and only a small increase in the yield of the lower stocking rate treatment. Again in Queensland, the loss of rhodes grass, glycine and Siratro in the 1968–69 drought was brought about by the combination of that drought with high stocking rates.

It appears that, at least for grazing–sensitive species such as *Themeda triandra*, grazing during any post–drought recovery period kills re-growing tillers which then leads to fewer reproductive vegetative buds (Mott *et al.* 1992). Intensive grazing threatens the persistence of our major desirable species. Legumes suffer from the double punishment of being highly palatable to livestock and susceptible to drought.

Because of the tendency for sown cultivated pasture species to be more attractive to stock, they are usually selectively grazed by livestock. In Australia, the loss of Siratro between 1968 and 1982 was mainly attributed to high set–stocking rates and below average summer rain (Jones and Bunch, 1988).

Such losses of pasture do not all occur immediately a drought takes hold. Gammon (1983) found in southern Africa, where veld condition was poor, that it was usually not due to a single drought season; rather is was a sign of years of mis–management over a number of drought years.

In a trial currently being conducted in Armidale to examine the mortality thresholds of a range of important perennial grasses under controlled conditions of drought and severity of defoliation, Boschma *et al.* (unpublished) have found that, when averaged over defoliation severity, more plants died in the 'common' drought (4 years in 10 drought) than in the more severe drought (1 year in 10) suggesting that plants are especially susceptible when attempting to grow from reserves in relatively common drought periods (Figure 6).

In the same trial, energy reserves as measured by the yield of etiolated regrowth following different defoliation strategies during drought showed more regrowth and therefore more energy for survival in those plants which had been moderately defoliated compared to those which had been severely defoliated (Boschma *et al.* unpublished) (Figure 7).

Figure 6 Effect of drought regime (rare [1 year in 10]; common [4 years in 10]; and no drought) on mortality of six perennial grasses subjected to drought and defoliation over the spring-summer season (Boschma *et al.* unpublished).

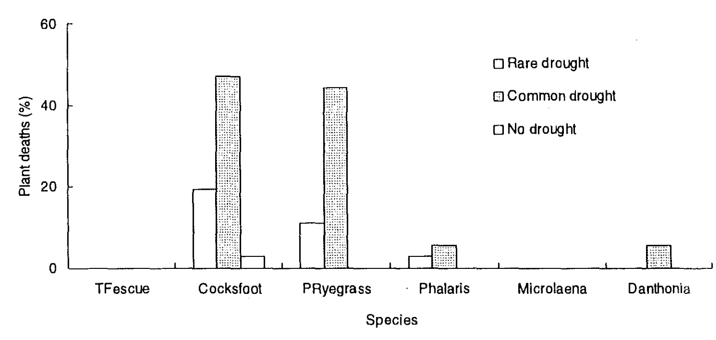
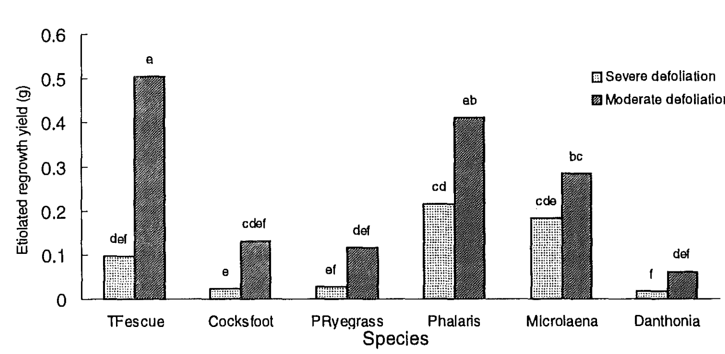


Figure 7 Effect of severity of defoliation on the etiolated regrowth of six perennial grasses following drought conditions over spring–summer (Boschma *et al.* unpublished).



Risk

The risk of overgrazing in Northern Australian beef systems is great in years of below average pasture production, especially where the combination of well–adapted *Bos indicus* cattle and legumes have become part of the system. Such amendments lead to more pressure on the system due to more nutritious feed, greater animal intake and the reduced buffering capacity of the pastures (McCown and Williams, 1990).

The study of movements in the Southern Oscillation Index (SOI) and its effect on rainfall is also believed to offer great potential to improve grazier decision making when faced with risk of drought; further evaluation of these indices is needed.

Erosion risk

The foundation building block of a productive system is its soil resource (Figure 2). The risk of soil erosion following the loss of protective plant cover, as can occur through overgrazing, can dramatically increase the risk of degrading this fundamental resource. McCown and Williams (1990) report that erosion risks are higher in years of low productivity. Thus, the loss of species is of importance not only for the pasture but also for the soil resources and the nutrients which the topsoil contains. It is widely accepted that ground cover by pastures of at least 70% is one of the most effective means of retaining soil in high intensity rain events.

Morley (1994a and 1994b) provides an excellent analysis of strategies for coping with drought in southern Australia and for calculating the probabilities of feeding/selling etc. Nevertheless, he recognises that all these strategies are linked with price changes and sustainability issues thus, whilst much good advice is given, a clear decision path is not provided, due to the number of factors involved. He also points out the specificity of drought problems faced in particular regions and times.

Makeham and Malcolm (1993) agree stating: "There can be no specific prescription for drought survival and recovery. Drought decisions will ultimately be based on individuals' situations and experience, and on their judgements of the situation. Having high equity and significant off–farm investments and income sources remain the most prudent steps to take."

Droughts are not a new phenomenon

Widespread droughts have occurred in Queensland over approximately 1/3 of years from the 1840s to the 1980s (Weston, 1988). Following previous serious droughts, publications have been forthcoming and the current (recent?) drought is no exception.

In 1995, we have seen the publication of 'The Drought Recovery Guide' (NSWA, 1995) and other similar publications in other States. In general, they focus on drought feeding strategies and, by their extensive coverage, recognise the complexity of facing drought and its consequences for soil, plants, animals, management, economics, the family and off–farm income. Whilst they provide an excellent guide, it is still difficult for the reader facing drought to be able to place priorities on recommended actions due to the numerous potential solutions put forward.

Stocking Rate

In general, stocking rate has an effect on the quantity and quality of feed on offer, the productivity per animal and per hectare, and on risk (soil, pasture, animal and economic). For example, McKeon *et al.* (1990) describe how stocking rate affects grass growth, basal cover, and animal production. High stocking rates have led to pasture degradation and, at times, soil compaction. The general relationship that exists between stocking rate and productivity shows high returns per cow at low stocking rates but higher returns per ha at higher stocking rates. At excessive stocking rates, the system can crash, resulting in loss of livestock.

However, as pointed out by Seligman *et al.* (1989), there is no optimum stocking rate: "the optimum stocking rate for a given situation depends not only on the input/output price ratios but also on the criterion for evaluating economic value that is most relevant to the manager".

In essence, graziers need to appreciate that balancing stocking rate within and between years is a real challenge as there is no static optimum stocking rate. When pastures are faced with grazing and drought pressures, then the stocking pressure needs to be reduced to ensure survival of the pasture.

Pasture Management

A range of pasture management options can be used to develop sustainable feeding strategies, especially in the 'high rainfall' zone where there are more opportunities to 'manage' than in semi–arid areas. Whilst no single method will deliver a sustainable system by itself, one can be used in conjunction with another to deliver the most economic feed for livestock production. The means farmers have to influence the productivity and persistence of their pasture resource include:

- ***Choice and establishment of desirable species***—choosing species well adapted to the soil and climatic conditions of a particular region can result in greatly increased productivity and lower inputs (*e.g.* using species well adapted to acid soil). This can result in a doubling of pasture productivity and an increase in quality, thus trebling animal productivity. Once established, management is needed to ensure persistence, especially in drought;

- ***Fertilizer strategies***—highly beneficial to responsive species and increases plant persistence in drought. If fertilizer is not applied, system will eventually become nutrient deficient as nutrient reserves in the soil are exploited;
- ***Grazing management***—flexible grazing management is essential for the retention of valuable species and can increase utilisation of pasture growt;
- ***Stocking rate***—essential for stocking rate to be flexible whilst being controlled at levels which will not cause pasture degradation;
- ***Weed control***—essential during establishment phase. Long–term control can be provided at no cost by a vigorous pasture;
- ***Irrigation***—of a minor proportion of a grazing property can dramatically increase overall carrying capacity and minimise need to purchase feed during droughts;
- ***Fodder conservation***—cheaper than bought feed. If executed well, can be a cost–effective means of moving surpluses from one season to another and thereby reducing risks and increasing carrying capacity.

Future Strategies

The successful management of grazing enterprises both prior to and during drought presents significant challenges to the grazier. Some of the key principles are identified below:

Flexibility

Flexibility is essential and the argument is put well by the north Queensland cattle producer, Tom Mann (1993) as follows:

"Drought is an emotive word much cried about by producers and then bandied about by our politicians; but in reality, this is a dry continent, subject to wide fluctuations in rainfall. I personally believe that droughts, like staff and cattle, are just one of the many facets of managing a cattle property. Drought subsidies allow politicians to feel good as they give our tax money back to us. However, subsidies do nothing constructive for our industry and in many cases contribute to the degradation of our land. Any business needs to be kept flexible and in order to do this we try and keep as many options open as possible. This is particularly so in drought time. We are always early sellers. Sell and regret, but sell anyway. You will never go broke taking a profit and cash is much easier to store than either fodder or cattle."

"The key to long–term sustainability and short–term performance is flexibility in all aspects of management. Running the cattle business is no different to running any type of business. It can be likened to playing chess, except that it is more challenging. The rules keep changing and you have more than one opponent, hence the need for total flexibility."

Partridge (1992) also had some succinct words to say about drought on native pasture systems in Queensland such as *"Sell 'em or smell 'em!"*

According to Partridge, there are 3 aims of a good drought strategy:

1 Maintain long-term viability;

2 Prevent degradation of land and pasture (and thereby achieve point 1.); and

3 Provide sufficient cash flow for short-term needs.

These early de–stocking strategies in the rangeland areas of Queensland are an essential management tool. In the higher rainfall zone, where more options for pasture management are available, selective de–stocking is one of many options.

Diversification

Diversification is a highly desirable feature of a robust farming system as it provides buffering capacity against climatic and economic variability. For example, Figure 8 illustrates how better quality pastures can permit a wider range of livestock enterprises. Few options are available with poor quality pastures.

Capitalise on the good times

If we are ever to survive droughts better, we have to learn from the old adage to make hay while the sun shines. This applies not only to conserving feed but ensuring that farmers retain viable pastures which will grow rapidly when conditions are favourable. The lost opportunities from not having quality pastures which will produce in the good times and yet which can be managed for survival in drought are significant. Most grazing enterprises in NSW now rely largely on relatively poor quality pastures which have little productive potential even when favourable conditions occur.

In recent months (June 1995 ed.), fat lambs (selling for up to $70/head) were produced by some graziers using lucerne as a productive, drought tolerant pasture. A rapidly growing lamb with its ewe mother can eat 2.5 - 3.0 kg DM/day. The pasture can easily meet the demands of many ewes and lambs per ha provided that the growth rate is sufficient. Even during

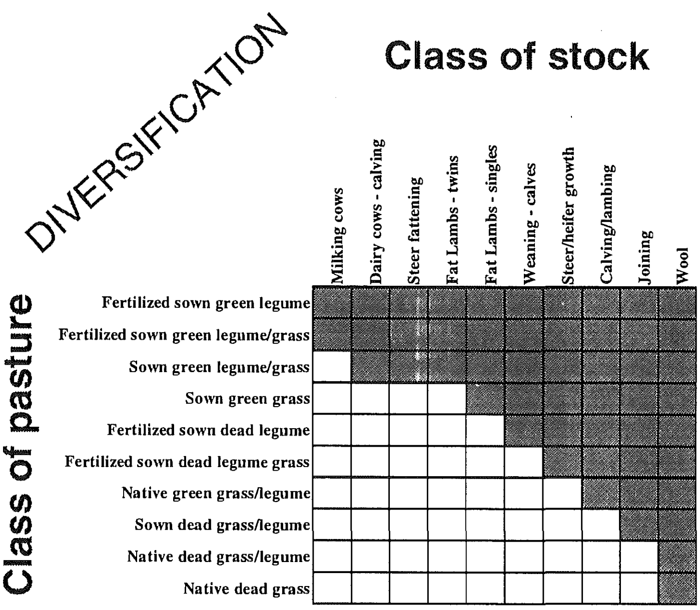


Figure 8 Relationship between class of pasture and diversity of livestock enterprises able to be carried on those pastures (shading indicates capacity of that pasture to support corresponding livestock).

a drought, when significant rain falls, as it does at times, the grazier is presented with an opportunity for significant growth of the cheapest form of feed for his livestock, provided temperatures are suitable for pasture growth. This growth can occur in spring, summer, autumn and even winter (for well adapted, cold tolerant species).

In a good season, a poor quality pasture may grow at rates as low as 10–20kg DM/ha/day which is in stark contrast to a productive pasture which can grow at rates of 50–100kg DM/ha/day. These high growth rates will quickly put the feeding balance sheet into surplus, thus avoiding the wastage of a growth opportunity.

Develop and protect natural capital

The natural capital of soil, pastures and animals is what ultimately leads to capital being put in the bank. We must show sufficient 'interest' in these layers of natural capital if the capital is to yield an adequate amount of 'interest'.

Soil Capital

Soil provides the foundation for plant and animal growth and thus its health is of paramount importance.

Attention needs to be given to:

- Preventing erosion by ensuring adequate plant cover;
- Avoiding significant compaction events which will diminish a soil's capacity to take up and release water;
- The maintenance of sufficient nutrients to enable pastures to grow rapidly when opportunities arise; and
- Maintaining sufficient soil microbiological activity through the retention of adequate organic matter in the soil.

Graziers need to see themselves as carers for the soil which ultimately supports their animal production.

Pasture Capital

Pastures provide the abundant, quality feed necessary for successful animal production. A good pasture is one which produces more product, contains a range of species so that anti–nutritional effects are minimised, produces better quality (*e.g.* less tender wool and more tender meat), permits less ground water recharge, results in better capture of atmospheric nitrogen, less leaching of nitrogen, less acidification, more infiltration, more water use, lasts longer before needing replacement and leads to greater resale value of land.

Whilst legumes are essential to sustainability by providing quality in the form of protein, a dominant grass component is usually necessary as it is the perennial grasses which can persist through drought, which out–compete invading weeds and which contribute the bulk of the total dry matter produced.

Once we achieve a good pasture it is essential that we retain it. Some form of flexible rotational grazing at critical times can ensure retention of desirable palatable species. Why is it that most graziers recognise the need for the rotational grazing of lucerne to protect its energy regeneration capacity and yet presume other palatable plants don't require similar rest periods?

Graziers need to view the production of an adequate quantity and quality pasture from healthy soil to be a necessary basis for the production of quality animal products.

Animal Capital

Whilst animals are also part of our natural capital, in drought times they are a disposable asset, albeit at low drought prices. This penalty needs to be weighed against the cost of feeding livestock through a drought and thus requires budgeting which takes into account input and output prices. By selling stock which require the best quality pasture and retaining stock with a low maintenance requirement, drought feeding strategies can be optimised. A committed selling program at the first sign of drought can result in much less pressure on the pastures and less need for bought feed. When faced with severe conditions, graziers need to be prepared to vary their stock numbers along with the feed supply. Nevertheless, wool production enterprises are much less sensitive to changes in the quality of pasture as wool can continue to be produced even during a drought.

Benefits

By maintaining pastures in a more productive and persistent state over many years, a grazier can reap benefits such as:

- Ensuring low costs per tonne of feed produced due to the low amortised cost of pasture replacement (this includes the costs of fertilizers necessary for continued production);
- Minimising the purchase of feed, thus reducing the risk of introducing weeds through bought feed;
- Minimising loss of soil or nutrients by wind or water erosion;
- Maximising the growth when favourable climatic opportunities arise even over short periods of only a few days; and
- Taking advantage of opportunities for production and high selling price not available to graziers without quality pastures.

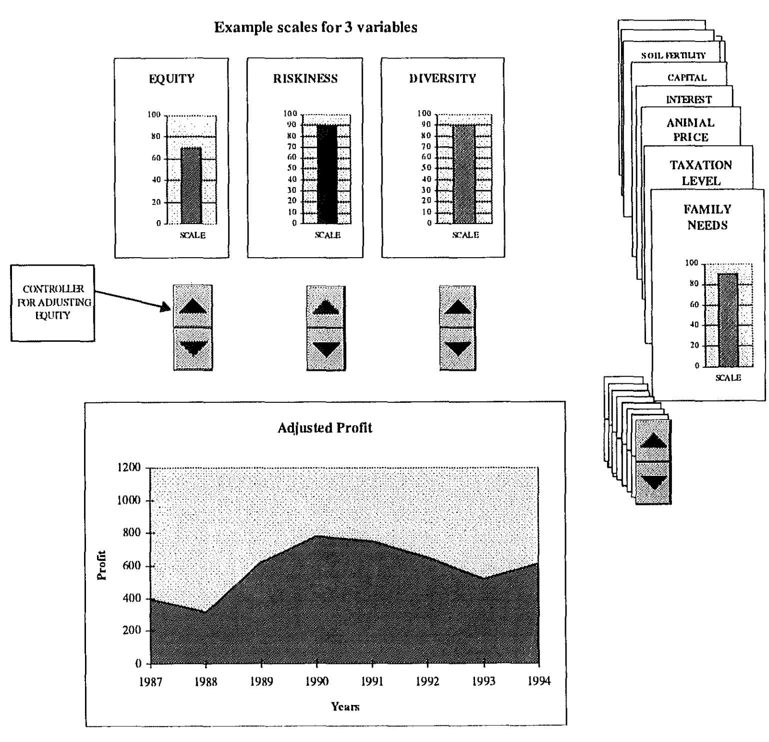
Time is of the Essence

As shown by Scott *et al.* (1992), consideration of a long time-frame is important for long–term sustainability. It is by using such analyses that the consequences of either good or bad short–term decisions become apparent in the 'bottom line'. As with all superannuation schemes which lead to benefits, extended periods are needed to accumulate significant interest on capital.

Learning to drive a complex system simply

Livestock enterprises based on grazed pastures in a variable climatic and financial environment are complex systems and yet graziers often manage their systems successfully with their 'seat-of-the-pants' wisdom.

Figure 9 A graphical view of a relatively simple interface to allow a user to investigate the effects of a wide range of farm–specific and other factors on medium–term profits. The profits estimate is based on the complex physical and biological relationships with climate in a model of a grazed pasture system hidden from view.



It is a challenge to be able to consider the whole system without getting confused by it. There is still a need to develop easier to use and more reliable tools to assist advisers and farmers to manage not only during drought so that disasters are avoided, but also during good conditions, so that opportunities are grasped.

Even though the system may be complex, I accept the graziers' often stated preference for the Keep It Simple, Stupid (KISS) principle of management. If this advice is ignored, the adoption of any improved tools will be poor. One schematic solution is presented below in Figure 9 where the operator can adjust any number of a wide range of factors to investigate the effect on projected profits over an extended period of years.

Future Needs—Conclusion

There is a need to develop an appreciation of the value of pastures as an economic feed source. Managing pastures for long–term productivity and persistence in a sustainable way is challenging, but will ultimately result in the most economic means of feeding livestock. More effort is needed to provide convincing evidence to graziers of the value of long–term investments in pasture feeding systems.

Much of the work done to date on risk and drought strategies has been done for the rangelands where management issues are much simpler. This research needs to be extended to other areas with more complex management issues, incorporating good biological understanding of grazing systems, and in a way which will deliver simple, yet credible, messages to managers.

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Pasture and Forage Crop Conservation—Hay and Silage

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Summary

Forage conservation is an important drought strategy available to producers in many regions of Australia, except in the low rainfall rangeland environments. Pasture is likely to be the most important resource available for hay or silage production, but in many areas forage crops will be a better option because of low or unreliable pasture yields and lower pasture quality.

Although Australia produces 5.43 million t hay and 0.85 million t of silage per annum (1991-93) this is not a particularly high level of production if it is compared to our combined cattle and sheep population. For example, if we were to feed our annual hay and silage production at the maintenance level of feeding to our entire cattle and sheep population it would provide only approximately 21 days feed. Most of the conserved forage is produced across southern Australia, there being little forage conservation in the north. In non-drought years average annual hay use has been approximately 94% average annual production so only a low proportion is set aside as a drought reserve. From the above discussion it is clear that there is considerable potential to increase the production of conserved forages in Australia, not only for drought but also for seasonal supplementary feeding and for production feeding purposes.

The paper briefly summarises the more important forage conservation principles, contrasting the differences between hay and silage. The reduction of field and storage losses have an important impact on the cost of hay and silage production. With good management field losses, both in terms of the quantity of forage lost and the reduction in forage quality, are lower with silage particularly during wet weather when hay losses can be very high. Storage losses can be a little higher for silage systems when compared to shedded hay, but they are lower when compared to hay stored outdoors.

Feedout management can have a significant impact on forage losses, animal performance, feed costs and profit. Feeding hay or silage on the ground can result in up to 50% wastage. The use of ring feeders can significantly reduce these losses and improve animal performance. Other important feedout management issues discussed are baled silage vs. conventional chopped silage systems, the importance of chop length on intake and animal production, and the aerobic spoilage of silage. In a production feeding situation the system used to feed out baled hay or silage could be important. Feeding bales in self-feeders or ring feeders could influence forage intake. It may, for example, be necessary to restrict the number of animals sharing a self–feeder and chop the silage if maximum intake and animal production are to be achieved.

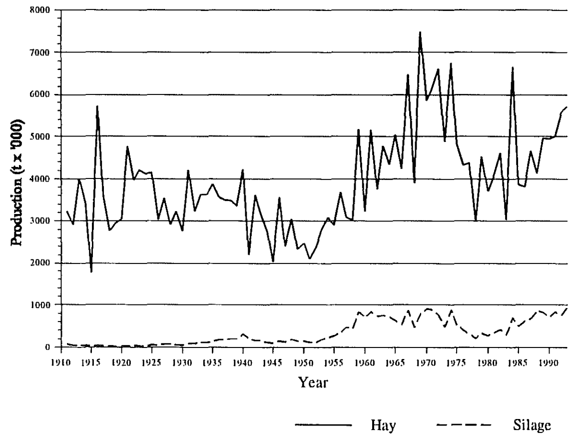
The quality of conserved forages determines the potential animal production that can be achieved from each tonne of hay or silage. It therefore has a major impact on the profitability of forage conservation. Hence targeting high quality is one of the most important management principles when producing hay and silage for both production feeding and drought feeding purposes. Cutting forage early, when quality is higher, is the most effective strategy to produce a high quality product. This is more difficult to achieve when making hay. Hence silages are generally of higher quality than hay. High quality silages will sustain high growth rates and can be used as the major feed component in finishing diets for cattle and lambs.

Apart from its prime role in providing additional feed, forage conservation can also be used as a pasture management tool leading to improvements in pasture utilisation, stocking rate, pasture production, legume content, weed control, and pasture quality. These benefits have not been included in economic analyses but could have a major impact on the profitability of forage conservation. In addition the use of legume-based forage crops for silage production in cropping areas could improve the nitrogen supply and reduce weeds and disease in subsequent crops.

Current Federal Government drought policy is to encourage greater self reliance among livestock producers. However, although forage conservation

would be an effective drought strategy in most environments, previous attempts to encourage producers to conserve forages for drought have not been particularly successful. We believe this is because forage conservation has been promoted for drought alone and because producers regard it as a high cost strategy (the cost of forage conservation is discussed in the paper). A better approach would be to promote its economic benefits for production feeding and pasture management (and crop rotations) with drought feeding as an additional goal. This approach, together with supporting research and extension programs and selective financial incentives to defray the cost of equipment, should increase adoption.

Figure 1 Hay and silage production in Australia, 1911-1993.



Forage Conservation in Australia

Forage conservation is an important management strategy on livestock farms in Europe and north America owing to the need to feed cattle and sheep through long, cold winters. Although our winters are less severe, Australian livestock producers still have to cope with a marked seasonality in pasture production both within and between years. Consequently, considerable resources are allocated to forage conservation. Current (1991-93) estimates of hay and silage production are approximately 5.43 and 0.85 million t/annum respectively (Figure 1) with hay production valued (gross) at $663 m/annum (ABS, various years).

To gain a better insight into the importance of forage conservation to the grazing industries the production of hay and silage should be related to stock numbers. An attempt has been made in Table 1 to assess the contribution of hay and silage to the feed supply for sheep and cattle in Australia. These calculations require a number of assumptions, and could overestimate the days of feed supplied by conserved forages as no account is taken of the hay sold off farm for feeding to horses or for export. However, these figures indicate that Australia's conserved forages would supply only about 21 days feed if fed at maintenance to the entire cattle and sheep population. When interpreting this estimate, account needs to be taken of the large differences in forage conservation between States (Table 2) and regions within States, and the large differences between grazing enterprises in the use of hay and silage for annual supplementary feeding purposes. Nevertheless the overall assessment is that on average conserved forages represent a relatively small component of the diet of our grazing animals.

Table 1 Contribution of hay and silage to the feed supply for cattle and sheep in Australia, 1991-93.

	Cattle (beef and dairy)	Sheep	Total requirement (hay equivalent)
Number (x 10^6)	23.87	149.85	-
Mean liveweight (kg)	390	37	-
Maintenance requirement[1]			
kg hay equivalent/hd/day	6.25	0.86	-
t hay equivalent/day	149,188	128,871	278,059

Total hay and silage production (t x 10^6 hay equivalent/year)[2] = 5.783
Daily requirement of Australian cattle and sheep (t x 10^6 hay equivalent/year) = 0.278
Days of feed supply at maintenance = 21

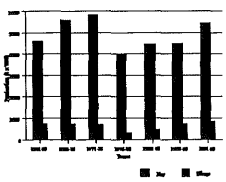
[1]Hay equivalent = hay at a dry matter (DM) content of 85%. Hay and silage assumed to have a metabolizable energy (ME) value of 8.5 MJ/kg DM.

[2]Silage assumed to have a DM content of 35%.

Production Trends for Conserved Forages

Long term hay production trends (Figure 1) show that current levels of production are now only returning to those observed over the period 1966-1975. Annual hay production dropped significantly (1.4m tonnes) during the 15 years 1976-1990 (Figure 2). Silage production followed a similar trend, although production over the period 1986-93 has exceeded the levels in earlier years. There is no clearcut explanation for these trends.

Figure 2 Five yearly trends in hay and silage production, 1961-1993.



Most hay and silage is produced in southern Australia, particularly in Victoria, with little production in the north. In Queensland, lucerne hay is the predominant forage conserved. Pasture hay is the most important conserved forage across southern Australia. Cereal hay is also an important conserved forage in the south (except Tasmania) and lucerne hay is important in eastern States. Silage accounts for approximately 6% of the forage conserved on a dry matter (DM) basis and production is greatest in NSW and Victoria. The proportion of silage is likely to increase with greater use of silage in the dairy and beef feedlot sectors and the adoption of baled silage technology.

Utilisation of Conserved Forages

There are few statistics available on the utilization of hay and silage but it is apparent that most is retained on farm with only a small proportion (perhaps 10-15% of hay) sold. Some cereal hay and lucerne hay is sold to feed horses and for export, and some lucerne hay and higher quality pasture hay is sold to dairy farmers. In NSW and Queensland the feedlot industry purchases cereal and some pasture hay, and a smaller proportion of lucerne hay. A relatively small proportion of silage is traded although some crops (*e.g.* maize, sorghum and cereals) are sold as greenchop for ensiling on feedlots and dairy farms. Contract forage cropping for sale as greenchop is likely to increase.

Most of the hay and silage retained on farm is used during the following 12 months for supplementary feeding, (maintenance and production) to fill seasonal feed gaps. There is however some carryover to cover non–drought between year variation in feed supply. Farmers also use forage conservation as an aid to pasture management and to improve pasture utilization. This is particularly important on improved pastures used for milk and meat production. There is also some use of forage conservation (particularly silage) for weed control and of hay/silage crops as a disease break in cropping rotations.

The proportion of hay and silage stored as a drought reserve is probably small. Using ABS statistics for hay and silage production, and hay and silage

Table 2 Hay and silage production in Australia, 5 year mean 1989-93 (t x 10^3)[1]

	Pasture hay	Cereal hay[2]	Lucerne hay	Other hay	Total hay	Total silage
NSW	524	229	372	2	1127	233[3]
Victoria	1667	205	162	22	2058	231
Queensland	68	25	170	3	266	72[4]
SA	364	221	85	10	680	37
WA	382[5]	430	12[5]	2	826	103
Tasmania	248	9	8	-	265	144
NT & ACT	11[5]	-	2[5]	2	15	3
Total Australia	3264	1121	811	41	5237	823

[1] Source: ABS, various years

[2] Cereal hay includes oat, wheat and barley hays

[3] Silage production statistics not available for 1991. Value presented is the 4 year mean

[4] Silage production statistics not available for 1991-93. Relative changes in production assumed to follow a similar trend to that in other States

[5] Pasture and lucerne hay statistics combined in WA, NT and ACT over 1991-93. Relative proportions of these hays in each State assumed to be the same as that over the period 1987-90.

Table 6 Initial liveweight, animal performance and costs of feeding hay on the ground or in a feeder to Murray grey weaners.

	Hay fed on ground	Hay fed in feeder
Initial liveweight (kg)	245	243
Liveweight gain, Feb-Jun (kg)	39	57
Hay offered (kg/head)	350	295
Hay cost ($/head)	35.00	29.50
Supplement cost/gain (cents/kg LW)	91	51

Source: Tudor *et al.* (1994)

Conservation Losses

Field Losses—As with hay making there are three sources of field losses - plant respiration (biochemical), mechanical losses and weather damage. While some mechanical losses (DM and quality) are unavoidable with hay making these are negligible with silage making (Wilkinson 1981), although they will increase if the forage is heavily wilted.

Losses due to respiration and weather damage are also considerably less with silage than with hay making (Kaiser and Curll 1987). Respiration losses are influenced by the speed of wilting and temperature, losses being greatest when forage is wilted slowly under moist warm conditions. Generally respiration losses during silage making are low if rapid wilting is achieved or where the crop is unwilted, but under poor wilting conditions DM and quality losses are increased. In addition the silage fermentation can be adversely affected if there is excessive loss of plant sugars due to respiration. This may be important in forages with low sugar content, for example legumes and summer growing (tropical) grasses.

Rain damage can dramatically increase hay making losses and in a worst case scenario result in a total loss. The effect on silage DM and quality losses is considerably less. In a European study Van Bockstaele *et al.* (1980) found that DM losses during field wilting increased from 3.9% without rainfall to 9.8% with more than one day's rain. Rain on only one day had a negligible effect on losses.

Storage Losses—Storage losses include those due to respiration and fermentation, effluent losses and surface waste. Some DM losses due to respiration and fermentation are unavoidable but are generally below 6% provided the desired lactic acid fermentation occurs. Energy losses are less because while the fermentation leads to a loss of DM, the silage fermentation products generally have a higher energy value than the original substrates.

Effluent losses can be eliminated by wilting forage to a DM content of at least 30%, and surface waste can be minimised by effective consolidation and sealing during the ensiling process (Kaiser 1994). With good management silage storage losses are still higher than those from hay in a shed (6 *vs* 3 to 5%), but considerably lower than from hay stored outdoors.

Total field and storage losses in a well managed silage system should be kept to 15% of DM and 12% of energy. In a co-ordinated study across eight European countries comparing silages made from wilted grass or unwilted grass + silage additive, minimum silage losses of 12-15% were obtained by ensiling lightly wilted forage with a DM content in the range 24-33% (McDonald *et al.* 1991). The time taken to wilt forage to >30% DM would be greater under European condition than in Australia. A more rapid wilt would be expected to reduce DM losses.

Manipulating the Silage Fermentation

Good silage preservation with minimum DM and quality losses requires a silage fermentation dominated by lactic acid bacteria. An undesirable fermentation, resulting in the production of volatile fatty acids and extensive degradation of the protein fraction, can depress intake and animal production. Under practical farm conditions well preserved silages can be produced from a wide range of forages. Producers have two options available for ensuring adequate silage preservation–wilting and silage additives (Kaiser 1994). Wilting forage to at least 30% DM will improve the fermentation and reduce effluent losses. The optimum degree of wilt is in the range 30-45% DM. There is little advantage in wilting beyond 45% DM as there will probably be no increase in animal production and higher DM material is more difficult to consolidate to exclude air, and field losses would be increased.

In Europe, where wilting is often not possible, silage additives are widely used by producers. However, in Australia additives are less widely used, and with most crops and pastures wilting is becoming standard industry practice. The role for silage additives in Australia is uncertain. Where a rapid wilt is not possible, additives may give a cost–effective response in terms of reduced ensiling losses and higher quality (Kaiser 1994). Responses to silage additives in overseas studies have often been variable, and there is a need for more research, particularly under Australian conditions. For example, additives may have an important role to play in improving silage aerobic stability during feedout.

Feedout Management

The feedout management principles outlined earlier for hay apply equally to silage. Significant reductions in hay and silage losses and significant improvements in animal performance can be achieved by improving feedout management. This is important in both a production feeding and maintenance/drought feeding context.

An important practical issue affecting the adoption of silage is the availability of feedout equipment. Most producers have the capacity to handle both small and large bales of hay, and the same large bale handling equipment can be used for round bale silage or big square bale silage. Even though baled silage is more expensive than conventional chopped silage, many producers find it more convenient to handle and there is no need to purchase specialised feedout equipment. Hence in recent years there has been rapid adoption of baled silage. However, as silage production grows in Australia, more silage handling and feedout equipment suitable for use with chopped silage in smaller to medium size livestock enterprises is becoming available. At present most of this equipment is being imported from Europe. Current equipment prices range from \$5,000 for a shear grab, \$9,000 for a block cutter, \$15,000 for a combination block cutter/feeder, and from \$16,000 for a silage cutter/feeder that cuts silage from the silage face.

Another feedout management issue that is probably only important in a production feeding context is the physical form of the hay/silage supplement. Both the particle/chop length and presentation/packaging of this forage can affect intake and therefore production. With silage finer chopping will substantially improve production in sheep (Table 7), although the response is less with young growing cattle, and highly variable with adult dairy cattle (Kaiser and Havilah 1989). These results indicate that the performance of sheep on the long forage in baled hays and silages is likely to be depressed.

Table 7 Effect of silage chop length on the intake and liveweight gain of lambs.

	Long	Short
Fitzgerald (1984)		
Silage intake (kg DM/day)	0.57	1.13
Liveweight gain (g/day)	-6.0	150.0
Apolant and Chestnutt (1985)		
Silage intake (kg DM/day)	0.45	0.72
Liveweight gain (g/day)	37.0	100.0

The feeding of baled hay or silage in ring feeders is becoming a popular management system in some areas owing to low labour requirements and reduced feedout losses. However in a production feeding situation what is the effect on silage intake? This question has not been adequately addressed in research, but it may be necessary to feed baled silage (and hay) in the loose form or after processing through a bale chopper to maximise intake. These feed management issues could have an important bearing on the choice of silage production method. For example if it is necessary to chop baled silage to sustain a similar level of animal production to that possible on conventional chopped silage, then the producer would need to purchase a bale chopper (\$15,000 to \$20,000).

Another factor affecting feedout losses with silage is the problem of aerobic spoilage (heating of silage) which can result in significant DM and quality losses (McDonald *et al.* 1991). Aerobic spoilage is only a problem with some silages and can be influenced by the parent forage, silage DM content, efficacy of sealing, feedout management of silage face, and ambient temperature. Losses can be minimised by good management although our warmer Australian environment could exacerbate the problem. Silage additives may give worthwhile improvements in aerobic stability and their efficacy should be investigated.

Quality of conserved forages produced on farms

Hay vs Silage

Several surveys have been undertaken to determine the quality of both hays and silages made on farms in Australia. Earlier surveys showed that most (>70%) of the hay produced on farms is of low to medium quality with metabolizable energy values < 9 MJ/kg DM (Kaiser and Curll 1981). Jacobs (1993) surveyed the quality of pastures prior to ensiling and the quality of the resultant silage in Western Australia over a two year period (Table 8). Results indicated that the quality of the pasture was similar over the two year period, however there was a marked improvement in the quality of the silage in the second year. The author concluded that although there was an improvement in quality the range in quality indicates that many farmers still regard conserved forage as a bulk maintenance feed rather than a production feed and place little emphasis on quality.

In the first year of this study there was also a comparison of silage and hay quality (Table 9). The pasture harvested for silage had a higher nutritive value than that harvested for hay. Losses in DM digestibility were similar for both methods and the resultant silages were of a higher quality than the hays.

Table 8 Quality of pasture and resultant silages collected on farms in the south west of Western Australia 1990-1992.

	1990/91		1991/92	
	Mean	Range	Mean	Range
Pasture				
DM (%)	22.1	13.4-49.3	23.9	13.8-56.4
DMD (%)*	68.9	61.0-81.1	69.8	57.0-80.1
CP (%)*	14.1	7.3-23.4	15.2	7.7-22.4
WSC (%)*	15.3	6.6-26.9	11.1	2.8-18.6
Silage				
DM (%)	24.1	16.7-49.7	27.2	18.3-48.5
DMD (%)	64.5	56.7-70.9	68.7	55.1-81.8
CP (%)	13.1	6.1-21.1	14.6	7.0-23.8
pH	4.0	3.6-4.5	3.9	3.4-4.9
Lactic acid (%)	5.8	1.2-9.7	5.4	2.0-10.7

* DMD, CP and WSC are DM digestibility, crude protein and water-soluble carbohydrates (sugars) respectively.
Source: Jacobs (1993)

Table 9 The nutritive value of parent material, conserved silage and hay sampled in the south west of WA, 1990/91.

	DM digestibility (%)		Crude protein (%)	
	Silage	Hay	Silage	Hay
Pasture	68.2	64.9	14.0	11.3
Conserved feed	64.5	61.5	14.2	10.3
Change (%)	-5.4	-5.2	+1.4	-8.8

Source: Jacobs (unpublished data)

Table 10 A comparison of the nutritive value of silage and hay produced on farm, in south west Victoria, 1994/95.

	Silage	Hay
DM (%)	47.2	87.7
	16.5-78.9	74.5-93.3
DM digestibility (%)	66.0	62.0
	56.1-73.0	47.7-67.9
Crude protein (%)	15.1	11.8
	9.6-20.5	6.7-20.1

Source: Jacobs (unpublished data)

More recently (1994/95) a survey has been undertaken in south western Victoria and the preliminary results are in agreement with the above findings (Table 10). In Tables 9 and 10 the DM digestibility values for the silages would have been underestimated as DM was determined by oven drying; oven drying results in the loss of silage volatiles. The conclusion from these surveys is that silage is generally of a higher quality than hay but both methods produce a product of lower nutritional value than the parent crop. The implication is that irrespective of the system chosen, management can be improved to produce a higher quality product, and in the case of silage one that is of similar nutritional value to the parent crop.

Another important issue that needs to be considered when feeding hay or silage, or indeed any feed, is whether there is a risk of contamination with chemical residues. Chemicals applied to pastures or forage crops can be carried through into hay and silage and subsequently contaminate meat and milk. Hence minimum withholding periods and other restrictions applying to specific chemicals need to be observed.

Animal performance

The quality of conserved forages has a direct effect upon resultant animal performance. A limited number of studies have been undertaken to directly compare the two types of forage within an animal production system. In a four year study conducted in south east Victoria two farmlets using spring calving dairy cows compared conserving surplus pasture as either hay or silage. Results showed that on average 8% more milk and 12% more milk fat was produced when silage was used compared with hay. The increase in milk production was directly due to feeding a conserved forage of higher quality (DM digestibilities 68% vs 61%).

Jacobs and Zorrilla-Rios (1994) compared feeding either hay or silage as basal rations with grain to fattening cattle and observed significantly higher forage intakes and liveweight gains with silage (Table 11). They concluded that when cattle were fed a higher quality conserved forage (silage) less grain (1.5 *vs* 4.5kg/day) was required to achieve similar liveweight gains than with the more traditional forage (hay) based diets.

There is now ample evidence that with good management it is possible to produce high quality silages (ME > 9.5 MJ/kg DM) that can be used for production feeding purposes. In a series of experiment at Wagga Wagga with yearling steers (Kaiser 1994), five silages (mean ME content 9.9 MJ/kg DM) when given as the sole diet supported a liveweight gain of 0.96kg/day and 115kg gain/t silage DM. Precision–chopped silages have also supported liveweight gains in excess of 100 g/day in lambs (Graham *et al.* 1992; Table 7).

Factors Influencing Quality

Reducing losses during the conservation process and harvesting a high quality parent forage are the two strategies that producers should use to target a high quality hay or silage. The most important factor controlling digestibility is time of cut, and there is ample evidence in the literature demonstrating the improved animal production possible on early cut silages (*e.g.* Table 12). Animal production is sensitive to small increases in digestibility; Gordon (1989) reported a milk production response in dairy cows of 0.37kg/cow/day, and Steen (1988) a liveweight gain increase in steers of 45g/head/day for each 1% unit increase in silage digestibility.

Forage species differences can also influence the quality of conserved forages. Summer growing species are generally lower in quality than temperate species and there are also differences within species groups, and even between varieties within a species. Legumes have a higher nutritive value than grasses, and at the same digestibility legume silages will support higher liveweight gains in cattle (McIlmoyle and Steen 1980).

Table 11 Intakes, liveweight gains and feed efficiencies of animals offered forage based diets supplemented with different levels of barley + lupin concentrate mix.

	Hay			Silage		
Concentrate as % LW	0.5	1	1.5	0.5	1	1.5
Liveweight (kg)						
Initial	281	284	290	279	278	283
Final	321	349	365	357	380	375
DM intake (kg)						
Forage	4.36	3.86	2.82	4.99	4.26	3.58
Concentrate	1.39	2.90	4.47	1.45	2.94	4.39
Total	5.75	6.76	7.29	5.44	7.10	7.97
Liveweight gain	0.33	0.63	0.88	0.81	1.09	1.20
Feed:gain	16.3	11.8	8.2	8.1	6.6	6.8

Source: Jacobs and Zorilla-Rios (1994)

Table 12 Effect of time of cut on the growth of steers on perennial ryegrass silage.

	Time of cut		
	Early	Medium	Late
Cutting date (days after 1st harvest)	-	9	17
Silage digestibility (DOMD %)	70.7	68.3	65.3
Silage crude protein content (%)	14.4	12.9	12.6
Silage intake (kg DM/day)	7.2	7.0	6.7
Liveweight gain (kg/day)	0.92	0.78	0.60
(kg/t silage DM)	129	112	90

Source: Steen (1992)

Legumes also supply more protein than grasses and this is an advantage for both production and maintenance feeding.

Is Quality Important for Drought Feeding?

The trade–off of quality *vs* quantity is often debated by producers, irrespective of whether the hay or silage is to be used for production or drought feeding. To a large extent production costs are independent of quality. In a production feeding context the effect of quality on animal production and therefore profit per tonne of silage is more evident. However it is often argued that for survival feeding during drought quality is not important. This issue has been addressed in Table 13, where the costs of drought feeding a herd of 100 cows for six months using silages of different quality has been calculated. These data clearly show that producers should aim at producing a high quality drought reserve, as this will allow them to reduce the quantity of forage harvested, stored and fed out. An added bonus is that the same silage can be used for drought feeding or production feeding purposes, allowing greater flexibility in management. This is likely to be even more important in future droughts as the increased grain use by the beef feedlot and dairy industries is likely to place greater pressure on grain supplies and prices. In addition feedlots are also likely to place considerable pressure on hay supplies. High quality silages can replace a significant proportion of the grain in finishing diets for cattle and lambs, and cattle can also be finished on a silage–only diet.

Forage conservation as a pasture management tool

In a drought–feeding context, apart from the potential reduction in overgrazing when animals are fed hay and silage the linkage between forage conservation for drought and forage conservation as a pasture management tool is not obvious. Nevertheless the linkage is quite important as the economic returns from potential improvements in pasture management, along with those from using conserved forages for production feeding, will help to defray the costs of forage conservation for drought. Although there is little Australian data on the effects of strategic conservation cuts on the productivity of a wide range of pastures, there is sufficient evidence to indicate that pasture productivity and quality can be improved. Indeed some dairy farmers use silage production as a management tool on perennial pastures. In this role, silage is preferable to hay as the potential for earlier cuts and the lower susceptibility to weather damage provide greater flexibility.

There are a number of potential benefits when conservation cutting pasture for hay or sillage is used as a management tool (Bishop and Birrell 1975; Kaiser and Curll 1987):

- It can lead to improved pasture utilisation allowing an increase in stocking rate and production/ha;
- The practice can increase the legume content;

Table 13 Effect of silage quality on drought feeding costs for a herd of 100 non-pregnant dry cows 450 kg liveweight and fed for 6 months at maintenance.

	ME content of silage (MJ/kg DM)		
	7	8.5	10
ME requirement (MJ/cow/day)	53	51	49
Daily DM requirement (kg/cow)	7.6	6.0	4.9
Total silage requirement (t DM)	136	107	87
Total forage to be harvested (t DM)[2]	160	126	103
Silage production costs ($, @ $55/t DM)	8800	6930	5665
Interest on silage ($, @ 7% pa for 3 years)[3]	1848	1455	1190
Feedout costs ($, @ $15/t DM)	2040	1605	1305
Total production and feeding costs ($)	12688	9990	8160

[1] It is assumed that protein supply is adequate. Cows on the low quality silage may not consume sufficient DM to maintain liveweight.

[2] Assuming 15% total conservation (including feedout) losses.

[3] It is assumed that producers will regularly turn over their fodder reserve with an average storage period of 3 years.

- The use of silage can lead to reduced weed content;
- There is an increased pasture production (conserved and grazed);
- Improved pasture digestibility on the grazed and cut areas is achieved by maintaining grazing pressure during periods of rapid pasture growth; and
- Reduction in surplus dry residues allowing better regeneration of annual species in autumn.

These effects have not been adequately quantified for our pastures so it is difficult to estimate their economic impact. In addition there may be additional costs with the more intensive grazing and conservation systems (*e.g.* increased maintenance fertiliser requirements). Nevertheless the impact of forage conservation on whole farm productivity can be significant. For example, near Crookwell NSW, the introduction of a high quality silage strategy allowed a beef producer to increase his breeding herd by 20%, finish more weaner steers at a lower cost, improve the clover content and reduce the weed content of his pastures, and increase returns by $77/ha (Nixon 1994; Davies, pers. comm.). We need additional case studies but these observations highlight the importance of evaluating forage conservation in a whole farm context.

Forage conservation for drought

Forage conservation as a drought strategy is not an appropriate option for all producers. The unimproved rangelands areas, particularly in low rainfall environments, are generally unsuitable for forage conservation. In higher rainfall rangelands areas producers may be able to select suitable areas of native pastures for conservation or grow a special purpose crop. On improved or semi-improved pastures in northern New South Wales and Queensland there would appear to be considerable potential to increase silage production above the current very low level. However much of the forage available for silage production is of medium to low quality. For this reason the production of ammoniated forages (Kaiser and Curll 1987; Kaiser *et al.* 1993) might be a more appropriate conservation system. This process is likely to increase digestibility and its potential should be evaluated. Special purpose crops for silage production, such as forage sorghum and millet, sweet sorghum and grain sorghum, are likely to play an important role in northern Australia.

The greatest impediment to greater use of forage conservation is convincing producers that investment in this area is worthwhile. Following earlier droughts doubt was cast on the value of maintaining a fodder reserve for drought (Morley and Ward 1966; Butler 1975). Despite this, many observers believe producers need to be better prepared and the Drought Policy Review Task Force (1990) recommended that greater self-reliance within the farming sector was important. In recent research Jackson *et al.* (1995) examined the likely net cash position and the net worth position after 5 years following a number of drought strategies for a northern tablelands (NSW) property. Strategies included:

1 Agistmen;
2 Silage making;
3 Running steers instead of a breeding enterprise; and
4 Staged supplementary feeding, then selling if the drought continued.

Strategies 1 and 3 were superior to silage. Similar results were obtained in another study (Jackson 1995), although the silage strategy had a lower risk (the highest minimum net worth). The assumptions regarding silage making costs ($81/t DM) and feed equivalence to grain (6kg silage = 1kg grain) would have worked against a better result for the silage option. A factor working in favour of the agistment option was the assumption that agistment was always available within 100 km—this may not be the case in a major drought. The conversion of silage to grain equivalence for economic comparisons needs to take account of silage DM content and ME content (see Table 14). Current studies (Jackson, pers. comm.) have addressed this issue and have shown silage to be a cost-effective drought strategy.

Reducing costs

As indicated earlier one effective means of reducing forage conservation costs is to ensure that quality is high. This is important with both drought and production feeding. The other main cost reduction strategy is to increase machinery utilisation so that capital overheads are spread over a larger quantity of conserved forage. With silage Davies and Behrendt (1995) showed that overhead costs fall to a relatively low level once 500 t are made per annum (Table 15).

With variable costs (including labour) of $30-45/t DM for chopped pit silage and round bale hay (and $60-70/t DM for round bale silage), total costs of chopped silage or round bale hay are likely to be $70 or $50/t DM when 200 or 500 t/annum are made respectively. To achieve these economies of scale how do producers increase machinery usage and at the same time ensure that a high quality conserved forage is made? It is unlikely that this will be possible if producers are only conserving forage for a drought reserve. In these circumstances machinery may only be required in favourable seasons, and then only until a pre-determined maximum target drought reserve is reached. A number of cost reduction strategies are possible:

- Increase the quantity of forage conserved by producing hay and silage for both production feeding and drought purposes. Producers can use

Table 14 Comparison of conserved forages with grain on an equal energy basis.

	Grain	Forage quality	
		Medium	High
DM basis:			
ME content (MJ/kg)	13	8	10
Equal ME basis (kg)	1.00	1.63	1.30
Fresh (as fed) basis:-			
Silage			
DM content (%)	90	35	35
Equal ME basis (kg)	1.00	4.19	3.34
Hay			
DM content (%)	90	85	85
Equal ME basis (kg)	1.00	1.72	1.38

Table 15 Influence of capital investment and annual production on the overhead costs of silage making ($/t DM).

Capital	Annual silage production (t DM/annum)			
investment ($)	100	200	500	1000
50,000	47	25	11	6
100,000	93	50	22	13
200,000	187	100	44	25

Source: Davies and Behrendt (1995)

conserved forages for routine supplementary feeding both within and between years, or for full feeding (*e.g.* opportunity feedlotting) to supply specific markets. Davies and Behrendt (1995) have demonstrated that production feeding can be profitable;

- Increase the quantity of high quality forage cut by growing forage crops or manipulating pasture management. In some areas it is possible to spread the forage conservation period over more than one season by utilising a range of pastures or forage crops. However in other areas forage conservation may be restricted to one season, and the harvest window may be small. In these circumstances it may still be possible to grow forage crops or different pasture types, and manipulate harvest dates for various paddocks by varying closure dates and regrowth intervals. Although the harvest window for a particular paddock will be short, each of the above strategies could be used to extend the forage conservation season. Research is required on these management strategies to provide producers with specific recommendations;

- Spread the use of machinery over a wider regional area so that differences in forage conservation seasons between areas can be handled by the one machine. This strategy can be used by contractors or by producers syndicating forage conservation equipment;

- Encourage machinery sharing through methods such as syndication. As long as there is the will to share equipment, it is relatively easy to draw up a good business plan to operate the syndicate for the mutual benefit of members. Research, using case studies is required on the effects of forage conservation system and syndication on conservation costs; and

- Reduce machinery purchase costs. There are two main methods of achieving this. The first is to purchase second hand equipment, but this option could be uneconomic if repair costs and timeliness (reduced quality) costs expected from older equipment are more than the additional overhead costs incurred with new equipment. A second method used by some producers is to purchase new machinery directly from overseas, cutting out the middle man. This option requires some expertise but can reduce machinery costs.

Policy Issues

This paper has focussed mainly on the production of hay and silage on farm as a drought reserve. In situations where producers have no fodder reserves or have depleted their hay and silage stocks, they are obliged to purchase feed if they wish to retain livestock. In these circumstances the most cost-effective purchased feed on an energy basis is grain. Some roughage is usually required, particularly in cattle diets, and during a major drought stocks are depleted rapidly. During the current drought hay prices rose to between $200-300/t with $220/t a common price, and were considerably more expensive than silage produced on-farm ($78/t DM production costs and interest, Table 12). Significant Government funding was also used to provide freight subsidies to transport hays and other roughages, many of which were of very low quality. In the period July 1994 - May 1995 approximately $22m was spent on freight subsidies (livestock, grain and roughage) in NSW alone. If Governments are to reduce the cost of drought by encouraging greater self–reliance amongst producers, how can this be achieved?

Taxation incentives via investment allowances or accelerated depreciation have been suggested as two measures that could encourage investment in forage conservation. However, Douglas *et al.* (1995) demonstrated that these policies are likely to have little impact. Alternative policies such as a subsidy or rebate on purchased machinery are likely to have a more immediate impact (Drought Policy Review Task Force, 1990).

Other possible forms of Government assistance are as follows:

- The legal and accounting costs of establishing forage conservation syndicates could be subsidised;
- Encouragement of syndication in the Rural Assistance Authority could be achieved by lending finance to a syndicate on the basis of the security in machinery alone;
- The Project Officers in each state could train extension officers and develop extension packages on forage conservation. Tertiary institutions could assist here by upgrading training on forage conservation in their undergraduate courses; and
- Increased funding of R & D on forage conservation especially in the area of integrating forage conservation into whole farm management.

A mix of each of the above strategies is likely to encourage greater adoption of forage conservation but is important that the focus not be on drought alone. Producers need to be convinced that forage conservation has an important role to play on their farms for production feeding and pasture management.

Conclusions

Although forage conservation is a major activity in Australia, the quantity of forage conserved relative to the size of our grazing industries is not large. It is also apparent that despite the experiences of earlier droughts the quantity of hay and silage produced for a drought reserve is small and probably below 6% of annual production in non-drought years. In future droughts the growing feedlot sector could place even greater pressure on both the supply and price of grain and roughages.

Current Federal Government drought policy is to encourage greater self-reliance among producers. Yet during the 1993-95 drought large quantities of low quality hays were transported around eastern Australia at great cost to producers and Governments (freight subsidies). While forage conservation is an effective drought strategy in most environments, previous attempts to encourage farmers to conserve forage for drought have not been particularly successful. We believe that this is because forage conservation has been promoted for drought alone. A better approach would be to promote its economic benefits for production feeding and pasture management with drought feeding as a supplementary goal. This strategy together with a supporting research and extension program and selective financial incentives to defray the cost of equipment should increase adoption. Silage is the preferred option as it is less susceptible to wet weather, provides greater flexibility in cutting date, produces a higher quality product and is more suitable for long–term storage.

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Beyond the Herb Layer—Shrubs and Trees as Drought Reserves

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Summary

Although it is recognised that pasture is the major feed resource for grazing animals, trees and shrubs also contribute to the diet selected by stock in most environments. Once established, the deep rooted nature of trees and shrubs makes them more resistant to water stress than pastures, and this attribute may be used to provide additional feed for stock during drought. Edible indigenous trees and shrubs represent a natural fodder bank in Australian grazing systems, but are more often exploited rather than managed as feed resource. However it is now being recognised that trees contribute significantly to landscape stability and the long term sustainability of pastoral systems. This review paper explores the present use of trees and shrubs in Australian grazing systems and concluded that with the exception of mulga *(Acacia aneura)*, there are few indigenous trees managed as a drought reserve. Whilst there are other indigenous trees which are palatable to stock (Kurrajong, Saltbush, Wilga), their infrequent occurrence and slow growth makes them of limited value as a significant drought reserve. Many exotic trees have been introduced to Australia since settlement, but only two species, leucaena *(Leucaena leucocephala)* and tagasaste *(Chamaecytisus palmensis)*, have been successfully introduced into commercial grazing systems. It has also been noted that whilst there appears to be many new trees and shrubs which may be useful in sub-tropical and tropical environments (Calliandra, Albizia, Sesbania, Gliricidia), there are only a few (tagasaste, Robinia, Willow) with similar potential for southern Australia with its predominantly mediterranean environment. Information on the establishment, management and productivity of mulga in western Queensland, tagasaste on the sandplains of Western Australia and leucaena in central and northern Queensland is discussed in the paper. Additional recommendations for use can be obtained through the relevant departments of agriculture in Queensland, New South Wales and Western Australia.

Introduction

Grasses, legumes, herbs and forbs represent the major source of feed for grazing animals, and changes in their seasonal quantity and quality are closely associated with the capacity of rangelands to sustain commercial animal production. However trees and shrubs may also form part of the grazing animals diet, with some animals showing a greater preference than others for particular species. Many African grasslands have evolved with a variety of animal species which use every strata of vegetation, and trees in these environments add significantly to the sustainable carrying capacity of ruminants grazing this range. Ruminants are only a recent introduction to Australian grasslands which evolved under grazing by macropods, and with a few exceptions, indigenous tree and shrub species are not adapted to and do not represent a significant source of feed for grazing animals.

Whilst it is accepted that drought is endemic to Australia, the effects of drought on the profitability of grazing enterprises and ecosystem stability are exacerbated by the number of grazing stock being held before, during and after the drought has broken. The options available to graziers have been documented by Leng (1992), and involve decisions on how many and which stock to retain and at what level of production should be maintained. The inclusion of fodder trees and shrubs, either indigenous or introduced, as feed resources for use in drought is an alternative to supplementary feeding with expensive hays and meals (*see* Agfact P1.1.1. NSW Agriculture). Other forage based management systems have or are presently being studied for their potential to maximise feed availability to stock in a drought. These techniques usually involve better exploitation of water resources to extend the feed year. Shallow water storage dams have been used to grow forage crops and thereby extend the growing season in arid areas of northern Australian. Artificial ponded pastures have also been shown to be useful in central Queensland, where specialised grasses such as Para grass (Brachiaria mutica), Amity aleman (Echinochloa polystachya) and

Olive hymenachne (Hymemachne amplexicaulis) can be grown in water depths upto 60 cm (Wildin and Chapman 1987, Pittaway, Wildin and McDonald 1995). There also appears to be a potential for the use of some water weeds, such as Duckweed and Azolla to provide sources of high quality feed for use during drought. There are also a range of perennial shrubs which may be useful in Australian grazing systems, for example, Pigeon pea (Cajanus cajan) has been promoted as an autumn forage for cattle in Queensland and N.S.W. (Akinola *et al.* 1975, Norman *et al.* 1980) and studies are presently underway to re-introduce some of the perennial saltbushes (Atriplex spp.) to Australian grasslands (Warren et al. 1990; Warren *et al.* 1994).

However, there is presently too little information from which one can judge the comparative merits of each management system, and as will be demonstrated later, many of these techniques are only relevant in particular environments. Trees and shrubs are also used to better exploit available water by virtue of their deeper rooting systems, and this paper examines the potential of trees and shrubs to ameliorate the effects of drought.

The advantages of trees and shrubs as fodder sources in ruminant grazing systems may be listed as follows :

- The leaves are usually of higher quality (proteins, minerals, B-carotene) for a longer period than available grasses;
- Most trees and shrubs are highly palatable to stock;
- They are inaccessible to grazing once mature, thereby creating a manageable reserve;
- Trees and shrubs are less affected by temporary rainfall deficit by virtue of deep rooting system;
- They provide shade and shelter in extremes of weather; and
- They stabilise soils against wind and water erosion, particulary during drought when pasture has died off or been removed by grazing.

The disadvantages of trees in grazing system:

- They produce less edible dry matter per area of land than grasses when rainfall is adequate;
- They compete with grasses for available nutrients, water and light;
- Some trees and shrubs have a low palatability to stock;
- Management and harvesting are additional costs to production;
- There are difficulties in the establishment of some introduced species; and
- Some introduced species have the potential to become weeds.

Fodder trees and shrubs may be used strategically to enhance the quality of available forage in times of adequate rainfall, supplement low quality forages on a seasonal basis, or act as a forage reserve for use in short or long term drought. There are many species of indigenous Australian trees which have been used by stock in drought, but none have been cultivated specifically for this purpose.

This review is presented as three sections which evaluate the current and potential use of 3 fodder trees which are being used in Australian grazing systems.

1 Tagasaste (*Chamaecytisus palmensis*) is the only fodder tree/shrub to show potential for use in mediterranean and southern semi-arid environments, and the potential for this species as a drought reserve is explored.

2 Mulga (*Acacia aneura*) has been used in Queensland, NSW, and Western Australia as a traditional drought feed since the grazing industries were first established, and the current recommendations for its value and use are presented.

3 Leucaena (*Leucaena leucocephala*) has been used with great success as a high quality fodder in the tropics and sub-tropics and its potential for use in drier environments as a drought fodder is examined. The potential for the use of other tree species is also explored in these presentations.

The Use of Tagasaste as Drought Reserve

D.M. McNeill and C.M. Oldham

Introduction

Dann and Low (1987) assessed the role of native and introduced trees and shrubs in providing fodder for livestock from both laboratory and paddock determinations of their nutritive value. They concluded that most native trees and shrubs had relatively poor nutritional qualities and that their regrowth rates after harvesting were slow. hence, the value of such plants in livestock feeding programs was over-rated. By contrast, they concluded that some introduced species such as tagasaste and leucaena may present significant potential in suitable environments.

South western Australia has a Mediterranean type climate with predominantly winter rainfall and annual pastures. In most grazing systems, farmers budget for a nominal three months feed gap from late summer to early winter during which they have traditionally fed grain to sheep and hay or silage to cattle.

Tagasaste *(Chamaecytisus palmensis)* is a perennial leguminous shrub which is native to the Canary Islands off the north-west coast of Africa. It has been used as a source of fodder for domestic animals there for centuries. In the early 1870's, Dr Perez, a medical doctor based on the islands sent a sample of feed to Kew gardens in England stating that it had a potential as a fodder source for domestic animals. In 1879 Kew distributed seed to all the British colonies including Australia and New Zealand. Over the next one hundred years several individuals, such as Dr Laurie Snook, promoted tagasaste as an important new forage species that could provide the classic "green hay stack", but he had only limited success in selling the concept to farmers.

Commercial adoption of tagasaste did not expand until a small number of Western Australian farmers began experimenting with plantations on deep sands, particularly in the New Norcia and Badgingarra area just north of Perth. This soil type had been unproductive under annual crops and pastures. In the early 1980's these farmers developed cheap and reliable methods for establishing large areas of tagasaste, and a successful management system began to evolve. This system used a combination of direct grazing for 4 to 6 weeks in late summer/autumn to use the leaf and edible stem to replace hand feeding and mechanical harvesting to make all of the tagasaste available each year.

The edible fraction of tagasaste consists of leaf and stem up to a diameter of about 3 mm for sheep and 6 mm for cattle. In 1985/87, cutting studies using tagasaste growing on very deep sands at New Norcia, approximately 130 km north of Perth (500 mm annual rainfall with 400 mm in winter) yielded 3000 kg dry leaf and edible stem per ha per year. Parallel grazing studies yielded around 3000 sheep grazing days per ha per year or an estimated 3000 kg edible dry matter per ha per year when plots were grazed for one month per year in autumn (Oldham *et al.* 1991). The yields were approximately 4 times the 700 sheep grazing days per ha per year (2 dse) obtained from annual pastures on the same paddock in previous years.

In summer and autumn, the edible fraction of tagasaste contains 15 – 18% crude protein and an *in vitro* (pepsin cellulase) digestibility of 68 – 70% (Borens and Poppi 1990, Fortune and Bailey 1993). However, in a number of experiments over several years, liveweight gain of sheep and cattle grazing tagasaste over the summer and autumn has been lower than expected (Oldham *et al.* 1991).

Despite tagasaste's moderate nutritive value in the summer and autumn, the concept of planting it to replace grain or hay usually fed by hand to sheep and cattle in autumn is economically attractive and has been enthusiastically adopted by farmers (Oldham *et al.* 1991). More recently, experimental and commercial experience has shown that tagasaste can be grazed throughout the year by cattle with liveweight gains of around 1.5 kg per head per day from early winter to mid-summer and strongly suggests that it could be the forage base for a new cattle industry on sandplain (Oldham 1993). About 40000 hectares of deep sand has been established to tagasaste since 1987 (Maughan and Wiley 1994).

What about the 'green hay stack'?

Drought is not easily defined. Those parts of southern Australia that have a mediterranean climate experience an annual dry period of 5 to 6 months that would qualify as drought in most other environments. A good drought reserve should ideally be cheap, of at least moderate nutritive value and stored in such a way that it is available when needed. How well does tagasaste fit the role of a drought reserve?

Tagasaste is a cost effective forage in most years for the annual drought in Western Australia. However, intake by sheep or cattle can be drastically reduced by low palatability that often occurs after 3 to 5 months of no rain in summer. In addition, the nutritive value of the tagasaste, not eaten by livestock, can be very low in these circumstances. There is some anecdotal evidence these problems can be cured or partially cured by sun drying cut material but there is no experimental evidence that this is so.

However, there are three further problems. Firstly, tagasaste grown on deep sands is too productive to be locked up just in case it does not rain when farmers want it. Secondly, there is the problem of leaf shedding. Tagasaste that is not grazed regularly will flower in late winter and early spring, set-pod in December, and shed most of its leaves prior to the autumn feed-gap so there is little to no leaf available when it's needed most. The trees normally don't refoliate until autumn rains and there is no experimental data that we know of for the intake and nutritive value of shed leaf, pod and seed, although we expect it to be low.

Thirdly, it has recently been shown that tagasaste that has been grazed annually to prevent flowering and maximise the availability of autumn forage, can still shed most of its leaves after 4 to 5 months of hot dry conditions. This phenomenon is well illustrated by the following data from a trial conducted to examine the effect of grazing frequency on the production of tagasaste (Wiley and Maughan 1993). The tagasaste, at Badgingarra Research Station on the sandplain north of Perth, was intensively grazed with sheep either once or three times a year. The rainfall distribution was very different in the two years of the study (Table 1). In 1991/92, there was a very wet summer and rainfall was almost evenly distributed over the three periods. By contrast, 1992/93 was a dry summer with only 35 mm rain in the December to March period.

The trial began in April 1991 with both treatments being grazed then mechanically cut. The growth of edible material during the following 4 months (winter) was similar. At the end of this period, the 3 times a year treatment was again intensively grazed to remove all tagasaste leaf. This defoliation reduced growth over the next 4 months (Spring). However this was more than compensated for by the extra growth over the final 4 month summer period (see Table 1).

During the first summer (1991/92) rainfall was unusually high. In this summer soil moisture would not have been limiting plant growth, yet the ungrazed tagasaste almost stopped growing edible leaf and stem. At the same time the frequently grazed tagasaste reached its peak growth for the year. The second summer (1992/93) was also exceptional in that there was so little rain. Despite the long dry period, the frequently grazed tagasaste grew almost as much as in the previous wet summer. The ungrazed tagasaste actually lost edible dry matter due to leaf drop. More frequent grazing increased total feed production in a season with little summer rain (Table 1).

Also note that the site on the Badgingarra Research Station has produced almost twice as much edible dry matter as the Martindale site at New Norcia quoted in the introduction. The explanation for this may be a relatively shallow perched water table at the site on the Badgingarra Research Station rather than a difference in tree density or rainfall.

Conclusions and recommendations

Tagasaste has been shown to be a well adapted plant to the infertile sandplains of Western Australia, and has significantly increased cattle production from pastures in this environment. Effective use of tagasaste requires close attention to grazing management with more frequent grazing favouring sustained plant and animal growth. The information gained from these studies suggests that tagasaste plantations may have relevance to large areas of both southern and western Australia. It appears to have a dual benefit of providing not only forage of good nutritive value for stock in drought, but also by stabilising the highly erodable sandy areas of these states. The specific requirement of tagastaste for well drained soils is the primary limitation to its more general use in the cool temperate areas of Australia.

Mulga and Drought

P.W. Johnson and I.F. Beale

Introduction and history of use

Mulga (*Acacia aneura* F. Muell. Ex. Benth) is one of Australia's most important native fodder trees and has been extensively used as drought fodder since at least 1886 (Everist 1949). In that year, according to the "Charleville Times" of July 1947, Henry Riddell employed axemen to cut mulga for 60,000 sheep in the Charleville district of Queensland (Anson and Childs 1972).

Mulga is widely distributed in south west Queensland (19M ha) and across much of arid and semi-arid Australia, with mulga-dominated communities covering 1.5M km^2 or about 20% of the continent (Johnson and Burroughs 1981). Mulga is adapted to environments where the soil moisture almost always limits growth, but rain can fall at any time of the year (Nelder 1986). However, Nix and Austin (1973) note the absence of mulga in semi-arid regions experiencing regular summer or winters droughts.

Mulga varies considerably in it's growth form and structure. Variation in size and shape of the phyllode (leaf), the degree of winging in the pod and the height (2-15 m) and density (10-8000 stems/ha) of the community. Nelder (1986) reported that the highest development of mulga associations occur as open-forests on deep loamy red earths south east of Charleville in Queensland.

Table 1 Rainfall and estimated yields of edible dry matter from plots of tagasaste grazed each 4 months throughout the year or once per year in autumn in 1991/92 and 1992/93 (from Wiley and Maughan 1993).

Growth periods	1991/92			1992/93		
		Edible dry matter			Edible dry matter	
	Rainfall (mm)	Grazed every 4 months	Grazed once in Autumn	Rainfall (mm)	Grazed every 4 months	Grazed once in Autumn
April - July	180	900	900	260	1100	1000
August - November	225	2000	3000	310	2300	3000
December - March	215	2300	500	35	2000	-1200
Total	620	5200	4400	605	5400	2800

Mulga use and practical limitations

Mulga leaf within reach of grazing animals (up to 2m above ground) and any plants blown over by the wind are consumed by livestock at all times of the year. Mulga leaf can comprise up to 10% of the diet of sheep and cattle in any season (Beale 1975). During drought, mulga is lopped or pulled to allow greater quantities of leaf to the grazing animal. Chainsaws and modified wheeled or crawler tractors have replaced the axemen of earlier years (Anson and Childs 1972, O'Dempsey 1989). Mulga can be the main source of fodder for sheep and cattle during drought. It should be emphasised however, that the overuse of Mulga as a drought feed can lead to major environmental degradation as the trees may be destroyed in the process of feeding out. Hence the use of Mulga represents, in contrast to introduced species such as tagasaste and leucaena, a feed of last resort rather a component of a regular feeding strategy.

Anson and Childs (1972) identified four growth forms of mulga in south west Queensland each with characteristics requiring different systems of management.

1 Umbrella mulga—This form of mulga is most commonly used for drought feeding because of higher leaf yields and lower densities (40-1200 trees/ha). Utilisation without destruction of the tree is best achieved by breaking the leader branches with tree pusher bars, front end loaders or lopping with a chainsaw.

2 Whipstick mulga—Generally the leaves on this form of immature mulga are out of the reach of sheep. Due to high densities (2000-6000 trees/ha) whipstick mulga is commonly utilised by being either pushed or pulled down with a cable, chain or basher unit. Due to high densities and the flexible nature of this form of mulga, individual tree survival rates can be high.

3 Tall Mulga—This form of mulga cannot be lopped as the trees have long bare trunks. Drought feeding of this form commonly involves pushing or pulling trees down with either single tractors or pairs of tractors with chains. Utilisation without destruction is impossible.

4 Low Mulga—This form provides useful browse as it is available without any special treatment. During drought it is a poor source of fodder as leaf yields are low and dense stands (7000-12000 shrubs/ha) make cutting uneconomical.

The numbers of sheep fed on individual properties varies. Groups of 10000 to 20000 sheep have been fed at one point, though best results have been obtained with sheep fed in flocks of 5000-6000 or less (Anson and Childs 1972). The approximate numbers of sheep which can be fed in a 6-8 hour day using wheeled or crawler tractors varies from 3000 to 12000 (Table 2). Mulga can also be felled by chainsaws. In selected densities of scrub with tree trunk diameters of 10-20 cm yielding 9 kg dry leaf per tree it is possible for one person to cut enough scrub in 6 to 7 hours to feed 2000 sheep. Refuelling, cleaning and sharpening of the saw adds a further 2 hours per day. Feeding with tractors involves a large capital outlay which needs to be considered. Chainsaws are cheaper to buy and operate but the risk of accident and breakdown is greater. Delays in feeding caused by breakdown longer than 2 days leads to a serious decline in the condition of mulga fed sheep (O'Dempsey 1989).

Table 2 Approximate numbers of sheep that can be fed in a 6 to 8 hour day using wheeled or crawler tractors (Anson and Childs 1972).

Tractor size	Sheep fed daily		
35 - 50 h.p	3000	to	4000
50 - 70 h.p	5000	to	6000
70 - 95 h.p	6500	to	7000
2 x 95 h.p	10000	to	12000

Value and limitations of mulga as browse and drought fodder

Mulga is browsed by domestic, native and feral grazing animals in all seasons. However, despite a crude protein (CP) content of 10-14% it is regarded as only providing a maintenance ration (Everist *et al.* 1958). The low digestibility of mulga protein (35-40%) (Harvey 1952, McMeniman *et al.* 1981) has been related to the high levels of condensed tannins (50-170 g/kg dry matter) which may bind to proteins in mulga leaves during digestion (Gartner and Hurwood 1976). Because mulga is an important drought fodder for sheep and cattle in Queensland, much research has been directed at examining and overcoming the dietary limitations of mulga (McMeniman and Little 1974, Hoey *et al.* 1976, McMeniman 1976, Niven and Entwistle 1983, Pritchard *et al.* 1988, Pritchard *et al.* 1992, Miller 1992).

To summarise the Queensland work, mature sheep will consume 700-800 g mulga dry matter daily under dry paddock conditions. This intake provides only sufficient energy for the maintenance of dry sheep, and is insufficient to meet their protein requirements. Sheep consuming mulga require daily supplements of nitrogen (1-2 g), sulphur (1-1.5 g), phosphorus (1-2 g) and sodium (2-3 g) to prevent deficiency of these major nutrients. Such supplements would be best provided in the form of a lick (see Table 3).

Table 3 Mulga dry matter intakes required to provide a maintenance level of energy and protein for wethers and dry ewes at different liveweights (O'Dempsey 1995).

Liveweight (kg)	Mulga intake (g dry matter/day) Energy for maintenance	Protein for maintenance
30	790	1210
40	980	1710
50	1140	2000

Sheep on a predominantly mulga diet for extended periods show lower wool growth rates, loss of liveweight and increasing mortality rates. Heavy losses of ewes and lambs can be expected under these conditions unless nutrient supplements are provided. The following regimes may enhance the performance of sheep fed mulga.

- Dry lick supplementation has been used to supply minerals and protein (O'Dempsey 1989, 1992);
- Polyethylene glycol (PEG) is effective in binding tannins (Jones and Mangan 1977) and when fed to sheep (24 g/d) given mulga has improved nitrogen and sulphur digestibility, and increased wool growth (Pritchard *et al.* 1992). The high cost of PEG has prompted the investigation of alternatives;
- Tannin-active bacteria present in the digestive tract of feral goats, koalas and camels can improve the fermentation of tannin rich diets in these animals and enhances the utilisation of dietary protein (Brooker *et al.* 1994);
- Sheep on a mulga diet drenched with feral goat rumen fluid produced as much wool as sheep supplemented with traditional nitrogen, phosphorus and sulphur supplements (Miller 1992); and
- An enhanced inoculum, generated by continuous fermentation with mulga, as a substitute for crude feral goat rumen fluid is currently being evaluated.

Recommended strategies for feeding mulga

Before starting to feed, the following questions should be considered:

- For how long will I have to feed?
- How many stock can I afford to feed and of these how many should I feed?
- Shall I use new or second-hand machinery?
- Is it necessary to supplement with mineral licks?
- How can I manage the feeding to minimise land degradation and ensure the long term productivity of the property?

The Queensland Department of Primary Industries does not promote regular mulga feeding as a long term sustainable form of stock feeding and land management. An early decision to reduce livestock numbers is often better financially than a decision to feed all stock just because the mulga is available (O'Dempsey 1989). However, a number of properties 'farm' mulga in selected paddocks on a 15 to 20 year cycle. The Department provides advice on appropriate methods of feeding and supplementation for maintenance of core flocks or herds during drought periods.

It is recommended that stock be confined to specific areas when feeding mulga. This reduces the distances both stock and machinery have to travel thereby lowering the energy demand on stock and costs of machinery operation. The feeding of supplements to overcome protein, energy and mineral deficiencies is recommended (O'Dempsey 1989). After a break in the season it is important to continue feeding for at least four weeks. During this period livestock should be confined to small areas to allow growth and seeding of grasses on the remainder of the property. The area grazed should then be spelled and any areas of erosion given special attention (O'Dempsey 1989).

Mulga use and ecological implications

Droughts are characteristic of arid and semi-arid environments world wide and have been defined as a 'period of rainfall deficiency which results in biological or economic loss'. Most of Australia's mulga is restricted to semi-arid areas where droughts are common. In Charleville Queensland, a drought can be expected one in every five years. The frequent occurrence and long duration make droughts the most significant factor affecting land stability in mulga areas. As mulga is used as a fodder reserve for livestock, management of these areas during drought differs from that in regions dominated by perennial grasses. Management practises adopted before and after droughts have important implications for the stability and productivity of mulga lands (Pritchard and Mills 1986).

The fragility of the mulga lands of Queensland have been documented by a number of authors (Pressland and Cowan 1987, Mills *et al.* 1989 and Miles 1994). Dawson and Boyland (1974) identified the maintenance of excessive grazing pressure on sensitive mulga land types during drought as the main cause of land degradation. Mills *et al.* (1989) suggested that the maintenance of grazing pressure immediately following drought was also an important cause of land degradation. The threat of land degradation is primarily a result of the presence of mulga top feed which encourages the maintenance of stock numbers during drought at pre-drought levels. This leads to excessive and prolonged pressure on the remaining ground storey vegetation and can hasten processes such as loss of ground cover and removal of surface soil (Pritchard and Mills 1986).

Conclusions

Mulga is both widespread in its distribution and use as a drought fodder. It provides a valuable maintenance diet for livestock during droughts when stock would either die or need to be removed. When mulga is regularly relied upon as a part of a 'normal' production system, degradation of the fragile mulga landscape results. Prudent and skilful stock and land management is thus required to avoid an over reliance on mulga as a drought reserve.

Leucaena and Other Tropical Fodder Trees for Drought in Northern Australia

B.W. Norton and R.C. Gutteridge

Introduction and history of use

Leguminous and non-leguminous trees and shrubs are used as traditional feed sources in many tropical and sub-tropical parts of the world. In the past 50 years, many different species have been introduced into Australian environments in an attempt to improve the quantity and quality of feed resources for grazing sheep and cattle. In southern Australia, there has been little success (apart from tagasaste) in finding suitable edible trees and shrubs for stock, although the highly successful introduction of subterranean clover has perhaps overshadowed the need for such species. In northern Australia, early introductions of species such as *Acacia nilotica* (Prickly acacia) which quickly became a weed has made authorities and graziers wary of this technology (Carter 1994), and it is only in the last 20 years that significant research has been undertaken into the possibilities of integrating introduced trees and shrubs into our grazing systems. Most of the species currently being investigated come from higher rainfall areas of the tropics, and are intended for use in comparable environments in Australia. This field of research has recently been reviewed by Gutteridge and Shelton (1994).

However, some of these species do have drought tolerance and may provide sustainable sources of fodder in our semi-arid zone. This is particularly true of leucaena leucocephala (leucaena). Its response to water stress shown in Table 4 together with the drought tolerant shrub legume Seca stylo and a poorly adapted tropical tree legume Calliandra. In response to a similar water stress the leucaenas and stylos were able to reduce the moisture content of their leaves to the extent that they were able to keep most of them alive. The drought intolerant calliandra, on the other hand, shed and hence wasted the majority of its leaves.

There is no doubt that there are many different species of tree and shrub legumes which may fit particular Australian environments, but there are few which are as persistent, highly palatable and nutritious as *L. leucocephala.* Table 5 shows that leucaena compares favourably with lucerne as a high quality forage. There are 15 other Leucaena species from environments ranging from desert to rainforest which are presently being evaluated at the University of Queensland for cold, drought, acid soil, disease and insect tolerance, and it is possible that the present leucaena use could be extended into more southern and more arid areas of Australia in the future. It is for this reason that this paper presents information on leucaena use, but recognises that there are other species which may also play a role as fodder trees in our grazing systems.

Table 4 Drought tolerance indices of tropical legumes after severe water stress (Swasdiphanich 1993).

Species	Water use efficiency before stress (g/kg/week)	Drought tolerance parameters after severe water stress		
		Soil moisture (%)	Relative water content of leaf (%)	Fallen leaf (%)
Calliandra calothyrsus	1.6	13.0	49.5	90
Leucaena leucocephala cv Cunningham	2.6	12.0	33.0	25
Stylosanthes scabra cv Seca	0.6	11.9	22.8	2

Current use of leucaena

In northern Australia, leucaena has been the most widely planted exotic fodder tree legume. The generally accepted rainfall range for leucaena is 650-3000 mm (Shelton and Brewbaker 1994) but it may be possible under certain conditions to establish it in areas receiving as little as 300-500 mm per annum. The special advantages of leucaena are its strong perennial nature (half-life 50 years) (Jones and Harrison 1980), its high quality forage and its flexibility of use in animal feeding systems. Its high quality forage can be related to a number of factors including excellent palatability, digestibility and intake and high content of protein and minerals, low fibre and moderate tannin content which promotes its bypass protein value. Over 35000 ha of leucaena have been sown in the last 10 - 15 years largely in central Queensland. Most commonly, leucaena is sown in rows 4-10 m apart with grasses such as Green Panic, Rhodes or Buffel sown between the rows. Under normal (not drought) conditions these leucaena based pastures can be stocked at 1 - 1.5 beasts/ha producing liveweight gains of up to 1 kg/head/day (Wildin 1994).

What are biological and practical limitations?

The slow establishment phase of leucaena is the major factor limiting its more widespread uptake and use by the grazing community. After sowing it may take from 6-18 months before first grazing can occur and during this time good weed control close to young plants is of critical importance. Protection from grazing during this phase is essential for seedling survival. Soil type can also play an important role in leucaena productivity as it is poorly adapted to shallow, infertile and strongly acidic soils. Being a species of tropical origin, cool temperatures in winter reduce its growing season, and severe frosts may kill young seedlings. Since 1986, a sap-sucking insect known as the leucaena psyllid Heteropsylla cubana has severely reduced the productivity of leucaena, especially in the more humid coastal environments. This pest has been responsible for a marked reduction in the area sown to leucaena over the past ten years.

Feeding and management for drought use

Graziers should regard hedgerow leucaena not only as a regular feed source but also as a means of drought mitigation. Once established, the plant is remarkably drought tolerant due to its deep root system and physiological adaptation to water stress (Swasdiphanich 1993). These characteristics could be exploited more fully by developing appropriate management systems. For example part of the area planted to leucaena could be allowed to grow into tree form to provide standover forage for use in times of drought. The understorey herbaceous layer could be grazed normally and the tall leucaena cut or lopped when necessary to provide a high quality supplement to low quality standing herbage. The major drawbacks to this system are the high proportion of inedible woody biomass produced in tree leucaenas and the forage lost due to leaf fall under prolonged stress.

An alternative strategy would be to allow the leucaena to be utilised in a normal hedgerow system. In this system even under drought leucaena is capable of producing small amounts of high quality shoots sufficient to maintain microfloral activity in the rumen and allow animals to at least maintain liveweight. The inherent drought tolerance of leucaena makes it eminently suitable for use in drought mitigation in the sub-humid regions of northern Australia and the major strategy for its use in this role would simply be a matter of encouraging more producers to plant larger areas of leucaena. Strategies for its most effective use as a

Table 5 A comparison of the chemical composition of leucaena (*Leucaena leucocephala*) and lucerne (*Medicago sativa*).

Chemical components (g/kg)	Leucaena leaf	Lucerne leaf
Crude protein	259.0	269.0
Gross energy (MJ/kg)	20.1	18.5
Acid detergent fibre	204.0	217.0
Ash	110.0	166.0
Calcium	23.6	31.5
Phosphorus	2.3	3.6
B-Carotene	0.54	0.25
Tannin	10.2	0.1

drought reserve have yet to be devised but the experience of graziers who have utilised leucaena in the present drought should be taken into account.

Conclusions on the Use of Fodder Trees and Shrubs as Drought Reserves

The three species discussed in this paper are examples of trees/shrubs currently being used in Australian grazing systems. Each species occupies a specific climatic and edaphic environment and must be managed appropriately for optimum benefit. Fodder tree and shrub research in Australia has been poorly focussed in the past, with most findings being offered to the grazing community without recommendations for management in particular environments. Tagasaste and leucaena use has been adopted by graziers only after lengthy experimentation in their particular grazing systems, and it seems that there is a need for closer practical cooperation between the grazers and scientists if new species are to be introduced. There are many potentially useful trees and shrubs from Africa, Asia, Central and South America which would fit particular grazing environments in Australia (Table 6), but this is not sufficient justification alone for introduction. The potential of these species to become weeds, the impact of these new species on the landscape and the maintenance of sustainable populations of indigenous flora and fauna are important questions which must be addressed when new species are to be introduced. On the positive side, rapidly growing fodder trees and shrubs may be useful for the rehabilitation of degraded lands and there is good evidence to suggest that tropical tree legumes bring the same promise to the tropical grasslands of northern Australia as did subterranean clover to the temperate grasslands of the south. As land use intensifies, so will the need for this technology increase.

The broader question of how should forage resources be managed in a drought can now be revisited. Trees and shrubs with their deeper rooting systems allow better exploitation of soil water and nutrients and stabilise soils against erosion. Where grasses and herbs are the only source of feed available in an arid environment, there may be a good case for the introduction of fodder trees and shrubs to provide a better seasonal distribution of feed quality and

Table 6 Some fodder trees and shrubs with potential for use in Australian environments (adapted from Gutteridge and Shelton 1994).

	Climatic tolerance			
Species	Rainfall (mm)	Drought	Cool temperature	Frost
Acacia aneura	200-500	Very Good	Good	Good
Desmanthus virgatus	>700	Very Good	Medium	Medium
Acacia albida	300-3000	Good	Good	Medium
Acacia villosa	600-3000	Good	Medium	Poor
Albizia chinensis	600-3000	Good	Medium	Medium
Albizia lebbek	600-2500	Good	Medium	Medium
Chamaecytisus palmensis	350-1600	Good	Good	Good
Flemingia macrophylla	1100-3000	Good	Medium	
Leucaena diversifolia	400-2000		Medium	
Leucaena leucocephala	650-3000	Good	Poor	Poor
Sesbania grandiflora	>800	Good	Very Poor	Very Poor
Robinia psuedoacacia			Very Good	Very Good
Fraxinus americana			Very Good	Very Good
Amorpha fruticosa			Very Good	Very Good
Morus spp			Good	Good
Calliandra calothyrsus	700-4000	Poor	Medium	Poor
Codariocalyx gyroides		Poor	Poor	
Gliricidia sepium	900-3500	Poor	Poor	Very Poor
Sesbania sesban	>1500	Poor	Good	Poor

quantity. With the exception of the mulga lands, there is presently no information on the short or long term economic benefits of managing grazing systems in this way. Where any form of supplementary feeding is used as a drought management strategy, then the establishment and management of fodder trees should be considered as a comparable practice.

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An Approach for Analysing Financial Viability and Risk on Farms

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Summary

The National Drought Policy is aimed at developing self–reliance amongst farmers in terms of their response to climatic variability.

In this study, the RISKFARM model has been modified to examine the financial and risk implications of following common drought preparedness options. This has been done within a framework which acknowledges that drought risk is a subset of the total farm risk portfolio.

Many of the drought options examined represent longer term decisions for dealing with drought. These are compared to more reactive, short term tactical responses where the farmer is forced to act. The study method involved considerable interaction with farmer/ farm adviser consensus groups to capture the key financial/physical and drought management parameters for a range of farming systems.

The financial outcomes generated were of a probabilistic nature, allowing comparisons to be drawn on the basis of both the level and variation in financial performance. In general terms, results indicated that where drought (or other adverse circumstances) last several production cycles, both management and taxation options would do little to offset poor financial performance. Some management options outperformed others, but overall the improvements were small relative to the possible range of financial outcomes.

While traditional management strategies appear to cope well with expected climatic variation, the scope for responding to severe drought appears limited, indicating that making the most of good seasons, limiting losses in poor seasons and access to off–farm income may be the most robust drought preparedness strategies.

Several taxation options (tax averaging, income equalisation deposits/farm management bonds and livestock elections) were also investigated. The general conclusion is that using one tax smoothing instrument can provide substantial financial benefits, adding extra instruments to the portfolio provides little additional benefit. Since most farmers use tax averaging, it would appear that most financial gain can be extracted from concentrating on drought management options, as opposed to tax management.

Results also indicate that combinations of other moderately adverse conditions (*e.g.* below average prices and yields combined with higher interest rates) can be as financially devastating as prolonged drought. There is a need to treat farm risk in a total, rather than a partial manner. The RISKFARM model can be used to identify key farm risks as a step toward a more cost-effective risk management plan.

Introduction

This paper provides an over–view of current research in CARE dealing with financial viability and risk in farming systems. Much of the discussion is centred around the financial implications of drought preparedness strategies, however the techniques used are just as relevant for investigating other forms of risk faced by farming businesses. Using drought strategies as an example, the aim is to provide a flavour for the type of information which can be generated using the RISKFARM approach.

Before discussing the background, methods and results of this work on risk and drought preparedness, it is worthwhile presenting some common themes which emerge from the farming systems examined:

1 Drought–proofing appears to be an unattainable goal—there are strategies which can promote business survival in drought, but no strategy will fully negate the impact of prolonged, severe drought. The strategies examined in this study appeared to cope well with expected droughts; (about one every five years) but not severe droughts lasting two or more production cycles;

2 In the medium to long term, all drought strategies represent marginal adjustments. No strategy

examined in this study produced a quantum leap in terms of farm financial performance;

3 Drought is only one risk faced by the farm business. To become pre–occupied with drought to the exclusion of other risk factors is likely to be detrimental to business survival. Results of the study revealed that combinations of other factors could be as detrimental as severe drought;

4 Debt loads are a critical factor affecting the ability of a business to withstand the vagaries of the farming environment. Low debt levels improve the prospects for maintaining cash flow through drought;

5 The Government taxation system cannot save a business in severe, prolonged drought, or in other severe adverse circumstances. The use of a single tax-smoothing instrument (*e.g.* tax averaging) provides some benefits. Beyond that, the farm manager will reap most financial gain through astute farm management decisions; and

6 There is no 'general prescription' for 'the best' drought management strategy to follow.

Project Background

For the past two years, staff at the Centre for Agricultural and Resource Economics have been collaborating with staff of the NSW Department of Agriculture and the WA Department of Agriculture on a project entitled 'Analysing Drought Management Strategies to Enhance Farm Financial Viability'. This project is jointly funded by the Land and Water Resources Research and Development Corporation (LWRRDC) and the Rural Industries Research and Development Corporation (RIRDC).

The project is one of a number of projects funded by LWRRDC which examine different aspects of climate variability. A key objective of the project is to examine the financial and taxation implications of the common drought preparedness investments which can be made by farmers across a range of production systems (grazing, mixed cropping, cropping). This work is set against the backdrop of a National Drought Policy which emphasises drought preparedness, self–reliance and a phasing out of drought support mechanisms such as fodder and transport subsidies.

Project Approach

Some comments on economic analysis and modelling

It is fair to say that much economic analysis and modelling has been partial in nature. That is, it has focussed on small components of a farming system in considerable detail and 'solved' problems at that level without asking the question 'is this an important contributor to farm business survival' or 'what factors have the largest impact on farm business survival in the medium to long term'.

That is not to say that partial analyses provide worthless information—just that the information provided must be viewed in a broader context. In terms of assisting farmers, it is important that they are made aware of the big issues. For example, there is no point in pushing the virtues of wool futures to control price risk if wool production is the major determinant of business survival.

The other point to make about modelling is that all modelling is a gross simplification of reality. Time and time again it has been shown that farmers do not respond in the 'rational' profit maximising way that economic optimising models say they should. Ultimately, this is because models do not capture all of the elements of the farmer decision making process such as social, legal, personal and environmental factors (see Appendix 1).

These criticisms also apply to the modelling described here. However, the approach with RISKFARM avoids some of these pitfalls, namely:

- The model is whole–farm, so includes most financial considerations and provides a 'big picture view' which is often missed in gross margin analysis;
- Uncertainty in the operating environment is included;
- Model responses are based on responses elicited from farmers (where possible); and
- RISKFARM is a simulation model. It shows the range of possible outcomes with attached probabilities of occurrence and makes no attempt to prescribe 'optimum' strategies. The final decision about which strategy is most appealing is left to the decision maker.

RISKFARM

An important aspect of the funding agreement was that computer models used in the research were to be based on existing computer models, rather than devote resources to developing new ones. CARE had developed a prototype spreadsheet financial model, RISKFARM, which was further developed and used in this project. Similarly, WA Agriculture had developed several detailed biological models, namely MIDAS and MUDAS, which have been used in their research. It is largely the work with the RISKFARM model which is outlined in this paper.

The RISKFARM model has several unique features which make it suitable for investigating the financial impacts of drought preparedness strategies or other changes to farm operations/structure at an individual farm level:

1 All model development has been performed in conjunction with farmer groups and therefore captures many of the elements of farm financial modelling which the farmers feel are important;

2 It is a whole–farm model (*i.e.* includes gross margin, overhead, capital and business structure information) which captures financial information over a five year period in considerable detail;

3 It is stochastic, so explicitly accounts for key risks. That is, instead of representing important variables such as prices, yields and costs as single numbers. They can be represented as a probability distribution, so allowing for the variability in these parameters which occurs in real–world situations;

4 Farm structure and the shape/range of probability distributions are quite flexible. Therefore, information can be gathered from individual farmers and used in the model;

5 Detailed taxation modules have been added. Farmers are very interested in taxation matters; and

6 Climatic and biological influences have been added to capture some of the broad effects of drought. These have been linked to decision rules which cause the model to follow various drought preparedness strategies in response to simulated climatic events. There is considerable scope for combining RISKFARM with other biological models.

Figure 1 The Structure of the RISKFARM Model.

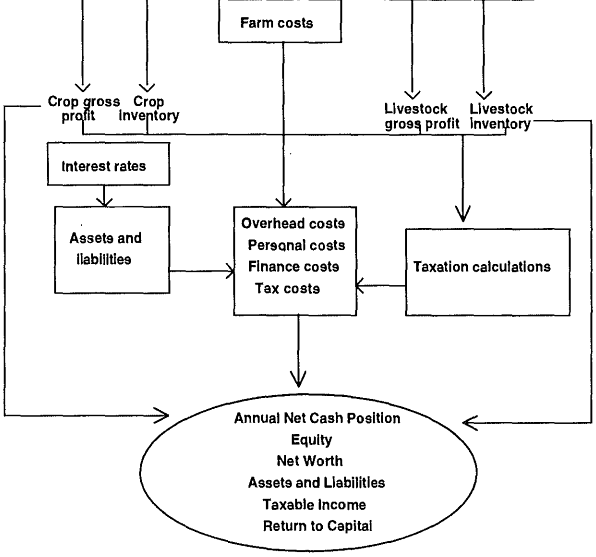


Figure 1 provides an over–view of the broad structure of the RISKFARM model, showing the key modules and how they are linked.

Project collaboration

Two important forms of collaboration were used so as to capture realistic farm structures and data:

1 Department of Agriculture regional economists and extension officers provided advice on the structure of farming systems; and

2 Local groups consisting of farmers and their advisers were used to describe feasible drought preparedness strategies for their region and to help construct demonstration farm models.

In all analyses involving RISKFARM, it is critical that data be gathered at a regional or local level so as to best reflect the circumstances of local farming systems. The use of more general national data often provides misleading results.

Results to Date

Seven different farming systems have been examined during the course of this project. These include:

- Western Division (Cobar)—wool production;
- Condobolin region—mixed wool/wheat production;
- Scone—beef production;
- Liverpool plains—cropping;
- Merredin (WA)—mixed sheep/crop production;
- Esperance (WA)—mixed sheep/crop production; and
- Northern Tablelands—wool and beef production.

Information supplied by local farmers on the most common strategies in the region was used to examine a range of drought preparedness options for each of these farming systems. In addition, several taxation instruments were examined. It is not possible to present the vast array of results generated here, but some specific examples illustrate the type of outputs being generated from the project and support the key findings listed at the start of the paper.

For purposes of clarification, it is necessary to define what is meant by the term 'drought' as the term means different things to different people. Drought definitions for this project varied with the farming system under examination, but all constituted a climatic event which required some management action by the farmer (for example, feeding or selling livestock or not planting crops). Climate indexes based on rainfall data were then constructed, which provided an historically accurate probability of those 'drought events' occurring.

Selling, feeding and other drought preparedness investments

Various combinations of feeding and selling strategies were examined for each region where applicable. These ranged from pure strategies of selling versus feeding (which produced the most contrast) to mixed feeding/selling strategies where, as the length of drought increased, stock were progressively sold and the remainder given supplementary feed (at either a maintenance level or a production level to maintain sale prices depending on the scenario under examination).

Figure 2 provides results for a scenario with the most contrast from the Scone system. The cumulative distribution functions (CDFs) show the probability of exceeding the level of net cash position given on the horizontal axis. Net cash position is the accumulated cash surplus or deficit after five years, after allowing for all farm income and expenses (including personal tax and finance expenses).

This CDF output provides several sources of information. First, any CDF entirely to the right of another is the preferred strategy since the probability of achieving a particular level of NCP is higher at all points.

Second, the actual probability of achieving a particular level of NCP can be read from the graph, giving an indication of the likelihood of performing at a certain financial level. Figure 3 shows a similar display of CDFs for a range of drought preparedness options for a Northern Tablelands property and their impact on Net Worth (the total value of all farm assets less all liabilities). The key point to be drawn from Figures 2 and 3 is that in spite of the fact that some strategies are preferred to others, the range of possible financial outcomes is still large. Employing a particular strategy does not convert a poor financial outcome into a good (or even reasonable) one under severe drought conditions.

Herein lies the problem with the concept of 'drought proofing' and 'self reliance'. Although these ideals may be attainable in droughts of short duration (perhaps up to 12 months in length), the amount of preparation that can be done for more severe droughts, is limited. No strategy appears to negate the severe adverse financial impacts.

The notion of choosing 'the best' drought strategy to follow (whether it be a long term strategy or a short term tactical response) is also fraught with danger. First, the best response will depend on factors operating at the time, such as the relative prices of different feeds and livestock or crop prices and costs. Some simple budgeting prior to choosing an action may be the most sensible approach here. Second, prescribing 'best' responses may cause adverse macroeconomic effects; if you advise everyone to sell, and they do,

Figure 2 Selling and Feeding Options for a Scone Beef Production System—Effect on Net Cash Position after five years.

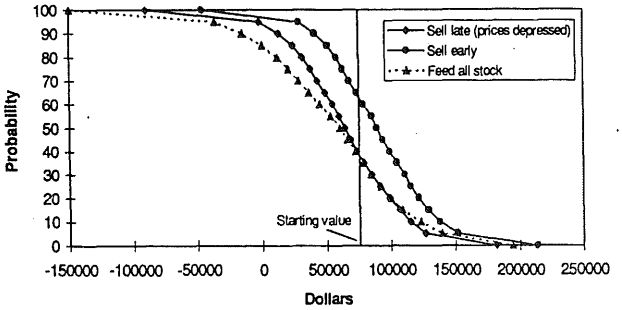
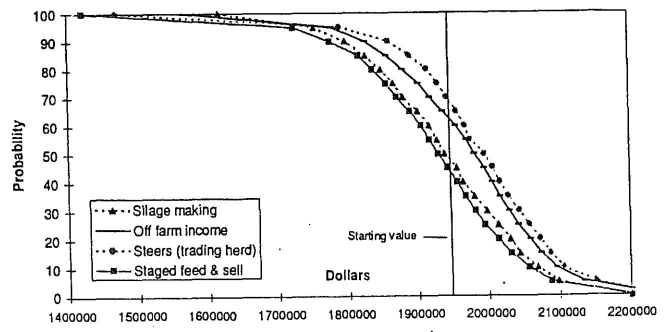


Figure 3 Some Alternative Drought Investments for Northern Tablelands Wool/Beef Properties—Effect on Net Worth After Five Years



prices can fall through over–supply. Third, differences in the structures of individual farms will call for different responses. Businesses heavily in debt may be pushed to failure if they borrow further, while those with high equity may be able to afford to borrow (see Figure 4 for an example of the cost effects of drought feeding).

Drought risk in perspective

It is important to remember that drought is but one of many risks facing the farmer. There is a probability that a drought of a given severity will occur, but there is also a probability that prices will crash, interest rates and costs will soar or disease will reduce yields. Table 1 illustrates this concept.

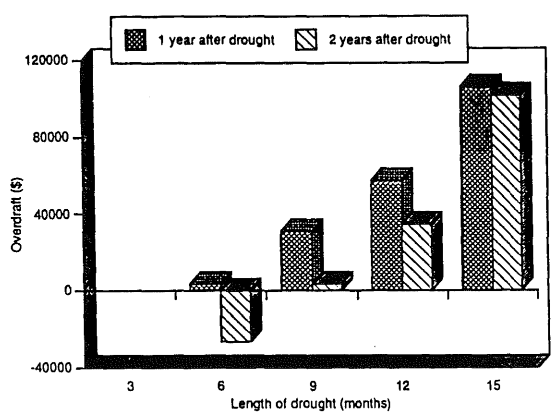
For the Cobar and Condobolin farming systems, the best financial performances were strongly linked to the absence of drought. However, note that the worst performances often had only one drought event in four years (23 percent probability of this occurring for the Condobolin system), therefore other factors were contributing to the financial problems. For Cobar, poor financial performance was more strongly correlated with longer droughts.

Developing risk profiles for a property

The RISKFARM software can also provide information on target levels of performance and the contribution of different risk factors to whole–farm risk. This has been termed 'risk profile' analysis. Figure 5 illustrates these concepts for a Northern Tablelands wool/beef property and shows the relative contribution of drought to whole farm risk as opposed to a range of other factors. This is done by 'locking in' a risk factor at its expected value (*i.e.* it is no longer risky) or, in the case of drought, altering the model so that drought never occurs and therefore no drought responses are activated.

Figure 5 shows how these risk factors alter the probability of breaking even after five years (breaking even means all income being able to cover all expenses). Compared to the base situation, removing the chance of drought causes a small increase in the likelihood of breaking even. However, this likelihood can be increased to a greater extent by removing the risks associated with wool yield and price. The other interesting point to note is that relative to the base case, none of these risks on their own contribute substantially to farm performance (*i.e.* removing the

Figure 4 Effect of Drought Feeding* on Business Overdraft Level for a Scone Beef Production System.



*Cost effects include cost of feed @$200/tonne plus interest on borrowing's at 10%

Figure 5 How Various Risk Factors Affect Farm Financial Performance on the Northern Tablelands.

Table 1 How Drought Influences Farm Financial Performance in Cobar and Condobolin Farming Systems

Region	Net Worth Performance Level (%)	Number of Droughts Over a Four Year Period			
		0	1	2	3
		Occurence (%)			
Condobolin	Best 10	70	23	7	
	Worst 10	25	37	33	5
Cobar	Best 10	98	2		
	Worst 10		27	62	10

risk related to any one factor does not provide a large increase in the likelihood of breaking even). It is the combination of risks which can create the very poor or very good financial outcomes thatare apparent in the CDFs shown in Figure 2 and Figure 3.

The rural taxation system

Primary producers have access to various taxation instruments designed to alleviate the negative impacts of having fluctuating incomes. These include:

- ***Tax averaging***—the tax rate applicable to farm income in any one year is based upon a moving average of five years income, so tax payments are smoothed;

- ***Income equalisation deposits/Farm management bonds (IEDs)***—a government scheme which allows farmers to deposit excess income into a fund in good years (this deposit is non-taxable) and retrieve deposits in poor years (this withdrawal is taxable) so as to smooth income; and

- ***Livestock elections***—income from forced sale of livestock (*e.g.* due to drought) can be spread over five years for taxable income purposes to smooth the tax burden.

The effects of these taxation instruments on net cash position after five years for a Merredin mixed farming system are provided in Figure 6. Again, the key message is that none of these instruments transform a very poor financial performance into a reasonable one. Tax averaging provides most benefits (largely through reducing the tax payable in high income years) and some 80 per cent of farmers use this instrument (B. Douglas, pers.comm. 1995). The other instruments do little to improve financial performance if used in conjunction with averaging. The other disturbing finding was that in many of the farming systems examined, tax concessions provided more benefits after a series of high income years than in low ones. In other words, the concessions appear to be having the opposite effect to that intended (*i.e.* to provide relief in poor financial circumstances).

Conclusions

Some general conclusions can be drawn from the analyses described above:

- Self–reliance and drought-proofing may be possible in short droughts but the strategies examined here did not negate the impacts of lengthy droughts, or combinations of drought and other unfavourable conditions. In the long term, most drought strategies analysed represented only marginal adjustments;

- It is critical that farmers maximise returns in favourable years and minimise losses in poor years as there are few options to improve farm performance in unfavourable years;

- Having alternative income sources and low debt loads are essential for surviving major unfavourable events. The ability to generate cash flow during these periods is important;

- Debt *per se* is a greater contributor to the likelihood of business survival in unfavourable circumstances than interest rate risks;

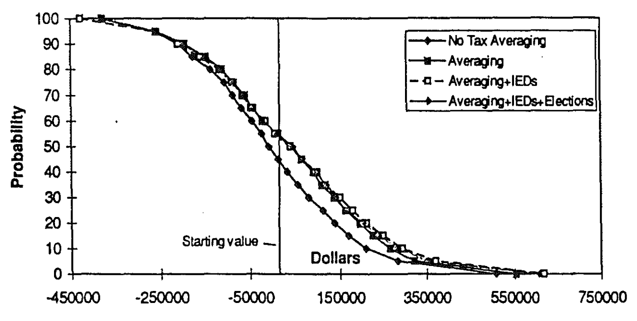
- It is impossible to be prescriptive about 'the best' drought management strategies and tactics in most situations because they will depend on the price and production factors operating at the time;

- Rural tax provisions do provide some after-tax benefits in high income situations, but these gains are minimal in unfavourable years. A single tax-smoothing instrument provides the bulk of the benefits. The need for several tax-smoothing options is questionable;

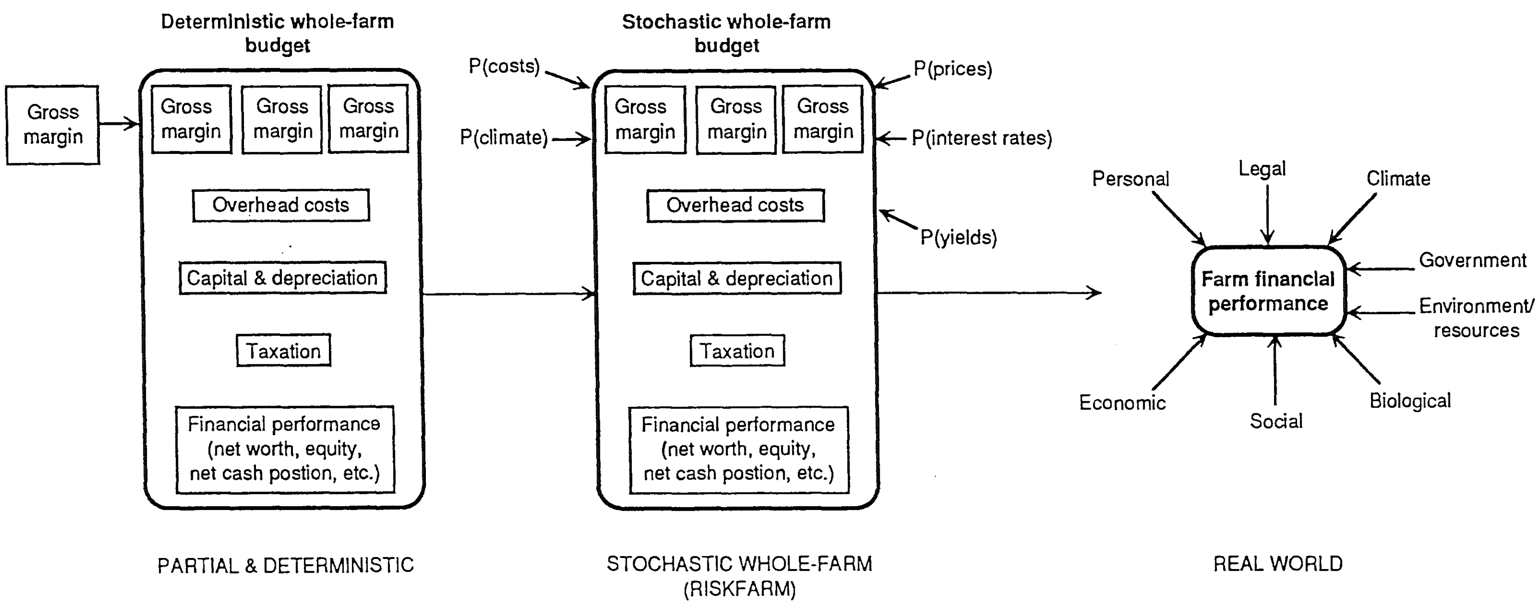
- The taxation system, through the rules on the valuation of inventory, actually hinders rapid adjustment to alternative enterprises which would enhance prospects for business survival; and

- The focus of the National Drought Policy appears to be somewhat misguided—drought is only one factor which can cause poor business performance. Other risk factors and combinations of risk factors need to be examined. This may have important implications for the exceptional circumstance provisions provided by government.

Figure 6 Using the Taxation System as a Drought Management Strategy—Effect on Net Cash Position After Five Years for a Merredin Farming System.



APPENDIX 1. The Process of Farm Financial Modelling



Note: P(*) = probabilistic variable

Drought Policy in 1995

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Introduction

Drought policy in Australia has changed profoundly in the last decade. From an institutional standpoint, more of the responsibility for policy is now borne by the Commonwealth than the states. In terms of the operation of policy, climatic variability increasingly falls under the broad umbrella of the Rural Adjustment Scheme (RAS). Indeed, many people are now arguing that traditional drought policy should be viewed as a political phenomenon i.e. they are arguing that drought policy is simply welfare policy.

However, whether drought policy is about welfare or national efficiency, it is important that it be discussed and analysed since there will always be potential for misconceived or 'bad' policy. It takes economic and scientific analysis to understand how climate influences farm incomes and the relationship between farm income and farm welfare. Good analysis is also needed to distinguish the nonsense from the genuinely useful information in the propaganda that accompanies drought. Likewise, analysis is needed to distinguish between what governments can do, should do and should not do.

Evolution of drought policy

It was Galbraith who said that a good policy analyst needs a 'living sense of history'. With that in mind, I will try to look at drought policy in terms of its evolution over the last three decades. There has been a basic shift in the rationale for, and implementation of, policy. We can distinguish three distinct phases in the past and I will conjecture a future fourth phase:

phase 1 efficiency phase (1945 to 1983)

phase 2 adjustment phase (1982 to 1992)

phase 3 welfare phase (today)

phase 4 political phase (future)

Efficiency Phase (1945 to 1983)

The 'efficiency phase' was where the 'average citizen' believed that drought policy served the common good and hence handouts were a good idea. This was reflected in the agricultural fundamentalism of the day which also profoundly influenced Australian culture and trade, and commercial and strategic policy. A vision of Australia as an agriculturally based economy led almost automatically to the view that farmers should be 'coddled' when it came to policy because drought was everyone's problem.

Adjustment Phase (1982 to 1992)

The 1982-83 drought was the most severe drought in forty years and led to re-thinking of drought policy. The seventies had seen reversals in policy on tariffs and trade policy and reductions in some agricultural subsidies. Against this background of policy reform, the government response to the 1982-83 drought was confused and viewed by most sides as being unsatisfactory. It was occurring against a political background where the 'average citizen' probably no longer believed in the common good arguments for drought handouts to farmers but was unwilling to see policy reversed while a major drought was actually occurring. Following the drought, serious discussion of drought policy by academics, politician and farmer representatives led to an erosion of many of the main efficiency based arguments for government sponsored drought relief. From the standpoint of policy implementation, this period can probably best be described as one of confusion as old ideas started to give way to new ones.

Welfare Phase (Today)

The political response to the current drought has been distinctly different to the response to the 1982-83 drought. The agricultural fundamentalism is virtually missing from the debate and drought relief has primarily been seen as welfare policy. Handouts to farmers are occurring in the context of other handouts going on in the community and the strongest political arguments for farmers have probably been equity considerations, i.e. the 1990 recession resulted in record levels of welfare payments to city dwellers and, since farmers are effectively ineligible for the dole, they were well positioned to ask for generous treatment under RAS provisions when the drought started seriously to effect their incomes.

Political Phase (Future)

Phase four is in the future and hence unknowable. I would conjecture it will be where farmers compete with others for handouts in a more politically transparent environment than previously, i.e. policy tradeoffs both within the agricultural sector and between agriculture and other sectors will be explicit.

There have been two factors driving the evolution of drought policy:

- The first is rising education standards in the broader community. Individuals are now more likely to be critical of economic policy and to demand scrutiny of how it is applied. Today people are better educated than in the past and can discuss a range of policy issues in a more informed way.

- The second driving factor becomes apparent if the (per cent) contribution made by agriculture to Gross Disposable Product is considered in Figure 1 (ABARE, 1994). Clearly, in national income terms, Australia no longer 'rides on the sheeps' back'.

  However, from Figure 2, agriculture still makes an important contribution to foreign exchange earnings. Just what importance should be placed on GDP vis a vis foreign exchange measures is controversial. However, both figures (1 and 2) indicate a secular decline in the importance of agriculture since the 1950s and this has doubtless been an influence on policy treatment of agriculture.

Efficiency Arguments

Efficiency arguments rather than welfare or equity arguments tended to dominate both the political rhetoric and the economic discussion of drought policy up until, and to some extent during, the 1982-83 drought.

Rhetoric over this period seemed to avoid welfare issues. The focus was primarily on 'keeping the farm going', or the infra-structure argument. The second major line of argument was along the lines that drought was a 'special' type of farm risk as distinct from other types of farm risk such as highly volatile commodity prices. Welfare was addressed indirectly through the disaster status of drought and no attempt was made to draw parallels between drought affected farmers and urban poverty.

Maintenance of Infrastructure

The dominant efficiency argument in the past has been that drought has the potential to seriously harm agricultural infra-structure and, by implication, harm the national economy. The view was that stock levels, farm investment and farm maintenance would fall to very low levels and agriculture would be 'crippled'.

These arguments were addressed in Freebairn's 1978 article in the Australian Journal of Agricultural Economics. Freebairn pointed out that historically stock numbers had always been rebuilt after drought. He argued that much of the dislocation associated with drought took the form of changes in ownership rather than actual 'destruction' of investment.

In this situation, demonstrating a 'public good' case for drought relief required that returns from public investment in agriculture were higher than returns from private investment. For this condition to be met, it would be necessary to demonstrate some sort of capital market failure in agriculture during and after drought. No such case has ever been demonstrated. To the extent that private flows of capital into agriculture during and after drought may be slow, this is more

Figure 1 Farm income as a per cent of national income.

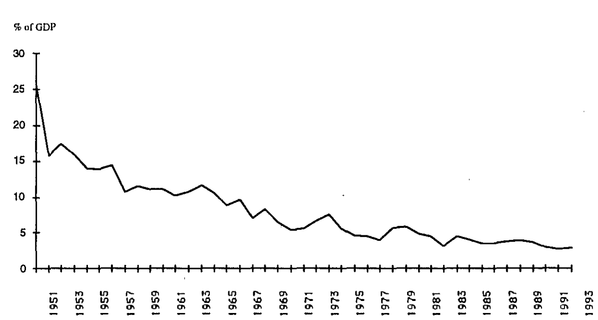
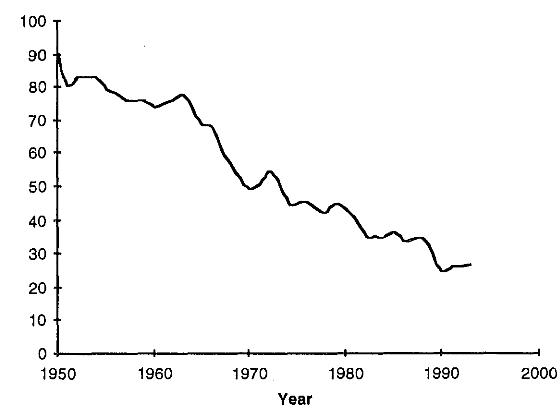


Figure 2 Per cent farm contribution to merchandise.



easily explained in terms of the riskiness of such investment than by any inherent problem with the way capital markets operated.

Drought is Special

The argument that drought was a special type of risk was implicit in much of the rhetoric that accompanied drought. However, it was never clear how drought was supposed to be differentiated from other types of farm or business risk. Kraft and Piggott dealt with this argument in their article in *Search* (1989).

In 1995 there is far greater awareness of what economists call 'externalities'. ('Externalities' occur where one persons behaviour or situation influences another person's welfare.) Oddly, drought as a form of risk may be special because it creates a special type of externality. Unlike other types of farm risk, it evokes a highly emotional response from urban dwellers, i.e. urban dwellers may be genuinely distressed by the environmental, animal welfare and general welfare implications of drought. The current drought has received far more sympathetic media treatment than the wool crisis ever did. Rural lobbyists have exploited this 'externality' in the past and no doubt will in the future. It remains to be seen whether it finds its way into policy in any explicit way.

Drought Policy Review Task Force

The Drought Policy Review Task Force (DPRTF) published its preliminary report in 1989 and then its final report in 1990. This report played scant attention to efficiency arguments for drought relief. Indeed it was 'thin' on just why the government should have a drought policy at all.

However the report did underline some important points:

New Philosophy

The report raised questions about who should bear responsibility for the effects of drought. It argued that responsibility for the effects of drought lay with farmers. Drought should be seen as a 'normal' part of agriculture:

> The need to manage for variable climatic conditions puts an onus on producers to adopt more flexible farming and management strategies (DPRTF Vol 1 p.4)

Not a 'Disaster'

The preliminary report of the Task Force resulted in drought relief being withdrawn from the umbrella of the National Disaster Relief Arrangements (NDRA). This was really part of the new philosophy. Drought was not to be seen by policy makers as a 'disaster' any more. It was a 'normal' part of farming for which farmers should be prepared for.

Environmental Costs

The report brought some focus on to the environmental costs of drought. The point that encouraging agricultural production during drought could harm the land had been expressed in a publication for the first time.

Separation of Welfare and Efficiency Elements

The task force argued for explicit separation of welfare and efficiency components in policy. There was a need for transparency in what had become a very murky area.

"...calls for a clear separation between those policies providing incentives to improve the operation of the market place and those aimed at providing government relief in times of hardship..." (DPRTF Vol 1 p.9)

Policy and DPRTF

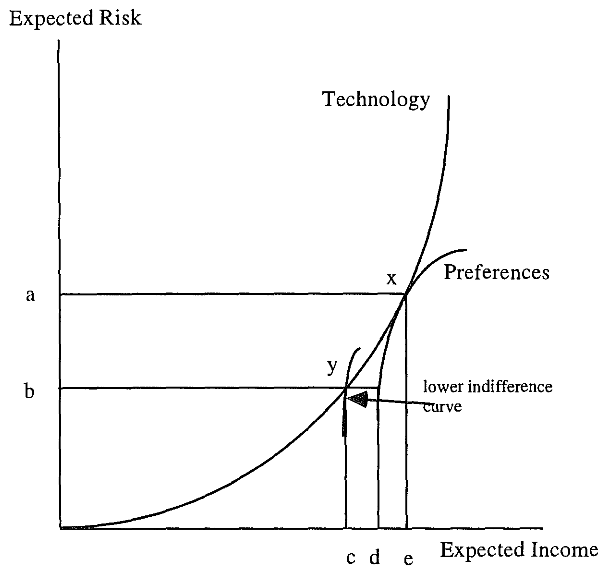
From a policy perspective, the Task Force report was a disappointment. It basically proposed a continuation of previous policies. However, a new perspective about policy did arise. This took the form of 'ex-ante' or 'increased preparedness' policy.

'Increased preparedness' policy advocated encouraging farmers to reduce their risk exposure. The proposals took the form of:

- tax incentives to undertake drought-proofing measures;
- encouragement of saving; and
- incentives for higher water and feed carryovers.

If agricultural policy debate ever reached a low in Australia, this was it. From an efficiency standpoint, paying farmers to reduce their risk exposure is silly. This can be shown using the following microeconomic model. In Figure 3 the technical possibilities for trading off risk and expected income are represented by 'Technology' and the farmer's preferences for this trade-off (or indifference curve) are represented by 'Preferences'. Farmers will not voluntarily reduce risk exposure by shifting production from x (the privately preferred point) to y (the socially preferred point) because they would then be on a lower indifference curve and hence worse off. Thus, to bring about the reduction in risk exposure to the socially desirable level of y requires a payment of \$(d-c) since this is the minimum amount necessary to put the farmer back on his or her original (pre-policy) indifference curve. After the policy, the farmer is no better off since he or she is now on back on his or her original indifference curve and tax payers are worse off by \$(d-c). No-one wins.

Figure 3 Paying farmers to be more efficient.



The second problem with this policy proposal is targeting. Since drought can strike anywhere, the whole rural community must be targeted. This is in contrast to 'ex post' policy where relief is limited to specific areas and farms.

1992 Reforms

The Commonwealth government policy response to the DPRTF came in 1992 (see DPIE (1992 a & b). The response had four important components:

Expansion of the Rural Adjustment Scheme (RAS)

Drought relief was to be dealt with under RAS provisions rather than separately. This was important because the RAS provided clearer guidelines than previous drought policy and RAS assistance had less 'strings attached'. In the past, relief often took the form of free hay or subsidised transport and the like and rarely took the form of cash. With the RAS, the major policy instrument is concessional interest rates.

Changes to the Income Equalisation Deposits (IEDs)

The new policy instrument was to be the Farm Management Bond (FMB), a type of farm bond. The bond reduces the cost to the farmer of holding cash reserves and is basically a subsidy to saving. As such, it is similar to the Income Equalisation Deposits scheme but has more favourable limits and interest rates. It will come into operation in July 1995.

Loosening up of Farmers Access to the Dole

A shift accurred in administrative responsibility to the Department of Social Security; fairly explicit separation of welfare and 'market facilitation' components were made.

Environment

A one off payment to LandCare for environmental preservation.

Research

Funding for research on drought related research.

These four reforms were in line with the DPRTF philosophy:

- Separation of efficiency and welfare components;
- Increased preparedness; and
- Importance of the environment.

Policy Today

In the aftermath of a severe drought it is interesting to see the form that policy is currently taking. Basically, the Commonwealth has stuck to its plan to use the RAS to help farmers. The scheme has expanded to incorporate a new group of clients and the major instrument has been concessional interest rates. Reforms to the RAS in 1992 meant that farms under severe financial stress now pay zero interest on borrowings.

Perhaps the most interesting point that is emerging is that welfare arguments are prevailing rather than efficiency arguments. The rhetoric seems devoid of 'keep the farm going' arguments and is focussing on hardship and the need for welfare based handouts. I think this is important for the future.

I think the trend away from efficiency based arguments for drought relief will continue. My guess is that farmers will shift the emphasis in rhetoric even further away from the efficiency based arguments and develop their political capital in the welfare arena. Surprisingly, I think that they will do well in this arena.

My reasons for thinking this are:

1 As a group, farmers are politically powerful by virtue of their location, numbers and cohesion. They always have had considerable political clout and are likely to continue to have it.

2 Farm lobbies have always been good at building political alliances. Note the current alliances to the greens and to the Australian Broadcasting Corporation.

3 As the lobbying power of the regional economies increases, agriculture will benefit from its association. The regional centres have increased their influence under Labor and have become electorally more important.

4 'City folk like farmers'. As urbanisation has increased, the rural myth has increased in power rather than decreased. If farmers increase their activity in the welfare arena they will have policies that are easily marketed by politicians facing urban constituents. This has already occurred in the USA, Japan and Europe where governments provide agriculture with high levels of subsidy.

5 Political markets appear to be more fluid than in the past. Farmers have a lot of their votes invested in CSIRO, export inspection services and the like. We are already seeing trade-offs between these policies and are likely to see more in future. Since cash and flexibility are always preferred by beneficiaries of government subsidies, it will be interesting to see how farmers trade-off government services for income stabilising policies such as drought relief.

It needs to be clearly understood that development of agricultural capital in the welfare arena is not equivalent to farmers being on the dole. Government transfer payments take many forms. For example, the Export Enhancement Scheme, which supports American grain producers, is not viewed popularly as welfare. However, it has no efficiency basis; it is really just a transfer payment from the politically not so powerful to the politically powerful.

Concluding Comments

Interestingly, in the current drought, some farmers seem to be less concerned about the effects of adverse climatic conditions on production than about adverse price movements associated with drought. They argue that during drought input prices go up while stock prices fall and that this is the real source of their problems. Presumably, this argument supports a policy proposal for governments to stabilise prices under adverse climatic conditions.

If prices rather than income levels were a focus for policy during drought then the policy framework would fundamentally change—In my view, for the better, since accusations about political favouritism and poorly targeted welfare resulting from government bungling would be by-passed. With a price based policy, farmers would make all their own decisions; however, they would do this in an environment of more stable prices. While the basic idea would probably be offensive to the strict 'rationalists' in government, there is a high level of disillusionment with rationalist economics and many agricultural economists could take a different view. Specifically, they may argue that since markets for risk are *missing* (in the technical sense) in agriculture, their is a case for offsetting uncovered climatic risk by reducing uncovered price risk. However, strong conclusions in this interesting area would need to be based on more research.

In the short term I believe that we will see change in two drought related policy areas: the Rural Adjustment Scheme and national level water policy.

Replacing the RAS

At a recent conference at UNE, John Freebairn said that 'there had to be a better way to get money to farmers than the RAS'. The RAS is a peculiar policy with some fairly distasteful properties. As a policy that subsidises credit, it distorts investment in the way that all input subsidies do. As a policy that improves welfare, it confuses efficiency and needs criteria. Also, it is often perceived as being unfair and inefficient. We know with certainty that the most efficient welfare comes with no strings attached.

The RAS is a costly way of having it all ways at once. If farmers continue to strengthen their political power and the direction of growth is welfare, the RAS is likely to be replaced.

National Water Policy

The current drought has threatened some regional urban water supplies and resulted in severe water restrictions in some country towns. Urban water demands are growing and it seems likely that competition between rural and urban water users will get stronger. This trend could result in drought policy being subsumed by national water policy. The nature of the drought policy debate could then change quite dramatically and farmers may not do well in the competition for government assistance.

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Current Commonwealth Drought Policies

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Summary

The National Drought Policy was agreed to by the Commonwealth, State and Territory governments in 1992. The current drought has seen the policy put into practice and highlighted the need for adjustments to policy settings. The Commonwealth has made a number of adjustments which have resulted in a more complete policy which provides support targeted at farmers in all economic groups. Profitable farmers are encouraged to prepare for future droughts, farmers who are unprofitable in the short term are provided with assistance to carry on their businesses and farmers unable to meet everyday living expenses are provided with welfare assistance. The Commonwealth's long term goal is to encourage a self reliant industry which manages the risks inherent in farming, reducing the likelihood that farmers will have to access welfare type assistance.

Introduction

Drought represents the risk that seasonal conditions will not be adequate to sustain normal agricultural activity. Within Australia's climatic patterns, drought can be seen as a regular event which inevitably affects Australian farm business, rather than as a natural disaster of rare occurrence. With this in mind, the National Drought Policy (NDP) was formulated to encourage farmers to manage their properties to take into account the risk of drought, a substantial change from the previous policy where drought assistance was provided through the Natural Disaster Relief Arrangements.

The NDP was agreed by Commonwealth and State Ministers in 1992. The policy is based on principles of sustainable development, risk management, productivity growth and structural adjustment in the farm sector. Widespread drought during 1994 necessitated some improvement in farmers' access to welfare payments and an enhancement of drought preparedness incentives consistent with the objectives of the NDP.

This paper provides an elaboration of the rationale behind the policies and programs now in place, while providing some background on previous drought policies.

Natural Disaster Relief Arrangements

Between 1971 and 1989, drought was administered by the Commonwealth Department of Finance and the State Treasuries under the Natural Disaster Relief Arrangements (NDRA). Under the NDRA, the Commonwealth assisted the States to meet the costs of providing natural disaster relief and restoration resulting from droughts. Under the arrangements, the Commonwealth provided assistance when the total outlays on drought relief by States exceeded its assessed capacity to service them. In effect, the quantity of assistance paid by the Commonwealth was directly related to the assistance levels paid by the States.

State assistance measures, part funded by the Commonwealth under NDRA included: concessional loans to farmers or small businesses whose assets had been significantly depleted by drought but who did not have reasonable access to commercial finance; and transport subsidies for fodder, livestock and water. The Commonwealth also provided assistance during the 1982–83 drought through its own program of fodder subsidies and concessional interest loans.

A major problem with the NDRA was that access to payments differed according to the drought declaration process in each State. Queensland, in particular, was in receipt of payments under NDRA for drought relief almost continually, while South Australia, the driest State in Australia, had no formalised drought declaration process and therefore only limited access to NDRA.

The type of assistance provided under NDRA was not particularly well targeted. Transaction based subsidies, as provided under NDRA, are not an effective method of providing assistance to drought affected farmers. Subsidies provided in this way: discourage self reliance; are not based on an assessment of need; benefit mainly the freight transporters and fodder suppliers; encourage overstocking; and are highly inequitable across industries.

The pressure for change for these arrangements came as early as 1982, when in the Balderstone Report, it was suggested that drought should be treated differently from other natural disasters and that farmers should do more for themselves. The final impetus arrived with the setting up of the Drought Policy Review Task Force by the Commonwealth Government, which began a review of drought policy arrangements in 1989 and provided a final report to Government in 1990. The National Drought Policy (NDP) arose from that review.

Managing for Risk, Productivity and Sustainability

Drought is one of several sources of uncertainty affecting the farm sector and is part of farming's normal operating environment. The financial and environmental impact of drought can be reduced by farmers adopting risk management practices which may also cover other farm risks, such as commodity price downturns and exchange rate fluctuations. These are the principles behind the 1992 NDP.

The specific objectives of the NDP are to:

- Encourage primary producers and other sections of rural Australia to adopt self–reliant approaches to manage climatic variability;
- Maintain and protect Australia's agricultural and environmental resource base during periods of extreme climatic stress; and
- Ensure early recovery of agricultural and rural industries, consistent with long term sustainable levels.

The Role of Farmers in Drought Policy

Under the NDP, farmers assume greater responsibility for managing the risks arising from climatic variability. This has resulted in the integration of financial and business management decisions with production and resource management to ensure the physical and financial resources of the farm are used efficiently. During the productive years, farmers are encouraged to build up reserves for use in less profitable times. On the other hand, during drought, farmers need to ensure that the intensity of farm production is not maintained at a level likely to cause long term damage to the resource base.

In essence, farmers need to undertake flexible stocking rate and cropping practices. Decisions about the optimal intensity of farm resource use in a given year need to be based on assessments of existing soil moisture content, pasture and vegetation cover, and the best available rainfall forecasts. Proper risk management will prevent excessive deterioration of stock or land conditions.

The Role of Government

Through the NDP, Government has created an environment conducive for farmers to undertake property management planning and a risk management approach to farming together with landcare activities to manage the natural resource base. Government has encouraged producers to adopt improved property management practices through a system of incentives, information transfer, education and training, landcare group projects, research and development.

The Commonwealth in consultation with the States and Territories has sought to ensure farmers are encouraged to cope with droughts and other economic downturns and to recognise the interrelationships between sustainable natural resource management and farm productivity and viability. Measures in place include provision for:

Autonomous Decision–Making

- The NDP is the cornerstone policy to ensure farmers become self reliant. A good example is the Farm Management Bond Scheme which encourages farmers to save money specifically for drought and other economic downturns.

Longer–Term Profitability and Sustainable Farmers

- To ensure farmers improve productivity on their farms, Government assistance is aimed at farmers considered to be viable in the long term. Those farmers unlikely to be profitable in the long term are provided alternative forms of support. The Rural Adjustment Scheme is the main program used and some of its funds are also directed towards training farmers;
- To encourage sustainable farming practices, the Commonwealth provides funds through the National Landcare Program (NLP) to community groups to develop skills and address natural resource management problems that are a common concern;

- Tax incentives are provided to farmers and rural businesses to invest in water storage and conveyancing, and to prevent and treat land degradation on private land; and

- In recognition of specific problem areas and regions throughout Australia where the sustainability of farming is at risk, the Rural Adjustment Scheme and the National Landcare Program provide support for regional initiatives that encourage the long term viability of farmers and address impediments to sustainable natural resource management.

Marginally Profitable Farmers

- For those farmers under severe financial stress, temporary welfare assistance is available. Farmers unable to borrow from commercial sources qualify for assistance under the Farm Household Support Scheme. Under the Scheme, farmers receive payments as a loan to cover everyday living expenses.

Unprofitable Farmers

- Farmers have access to Commonwealth welfare programs under similar circumstances to other Australians. In addition, farmers leaving farming and in receipt of Farm Household Support are eligible to receive part of their Farm Household Support payments as a grant;

- Unprofitable farmers can seek assistance to leave farming through the provision of re–establishment grants available under the Rural Adjustment Scheme.

Extreme Drought

- Where drought 'exceptional circumstances' have been declared, farmers suffering from short term financial difficulties as a result of the drought, may be eligible for welfare funding under the Drought Relief Payment Scheme. The payments are the same as the Job Search Allowance. Farmers are not required to exhaust commercial credit before accessing payments;

- Under exceptional circumstances, the Rural Adjustment Scheme is the means to facilitate interest subsidies for carry–on purposes. These exceptional circumstances can be declared in situations of extreme drought.

- Re–establishment grants, under the Rural Adjustment Scheme, are supplemented for farmers in exceptional drought areas.

Some of these programs receive joint funding by Commonwealth and State Governments. In addition, State Governments provide drought–assistance measures without Commonwealth funding. These measures, in general, should not compromise the overall direction of the NDP and are provided at the States' sole discretion and at their own expense. Agreement was reached, during 1992, to phase out transaction based subsidies as soon as possible. Given some States were in drought at the time of endorsement of the NDP, transaction subsidies are yet to be phased out by some State Governments.

Defining Extreme Droughts

A harmonised national system is now in place for considering:

- Drought declarations by State and Territory Governments; and

- Drought 'exceptional circumstances' declarations by the Commonwealth.

Central to this system is a framework for the determination of drought exceptional circumstances, and a set of six criteria to be taken into account by both the Commonwealth and the States in future of drought 'exceptional circumstances' declarations. The six core criteria are:

a) meteorological conditions;
b) agronomic and stock conditions;
c) water supplies;
d) environmental impacts;
e) farm income levels; and
f) scale of the event.

Drought 'exceptional circumstances' occur when the combined impact on farmers of the core criteria is a rare and severe occurrence. Meteorological conditions are the threshold or primary condition for such circumstances.

Under the national framework, the onus is on State and Territory governments to make the initial case, in terms of the above criteria, for the existence of exceptional drought.

In all circumstances, it is intended that the primary or prerequisite criterion will be meteorological conditions. Only if this criterion is satisfied will the assessment go further.

The remaining criteria should collectively indicate drought exceptional circumstances. The criteria are used together to form an overall judgment on exceptional drought circumstances.

A recent ARMCANZ meeting approved a similar process to be followed for the revocation of drought exceptional circumstances.

Policy Measures Available to Farmers

The Commonwealth's policy measures have been provided against the background of the National Drought Policy. Measures are designed so that: profitable and sustainable farmers are encouraged to remain so; viable farms become more profitable and sustainable and reduce reliance on government programs in the future; and the non–viable and unsustainable can re–establish themselves outside farming. At the same time the Commonwealth recognises that extreme droughts can occur. During such times the Commonwealth provides welfare assistance and carry–on finance. The Commonwealth's policies encourage farmers to become more self reliant by managing for risk while ensuring the long term sustainability of Australian agriculture.

A description of the specific policy measures available to farmers is provided below. The Commonwealth's policy measures are designed to: encourage farmers to become more self reliant farm managers; ensure the resource base is protected; improve the productivity of the farm sector; and for those farmers in severe financial stress, maintain the welfare of farm families.

Enhancing the Move to Self Reliance

Income smoothing and the creation of reserves can be useful tools in risk management. The Income Equalisation Deposit (IED) and Farm Management Bond (FMB) schemes seek to address these two specific policy objectives.

The current IED scheme has a number of features:

- Deposits are tax deductible in the year of deposit and assessable in the year of withdrawal with minimum sums of $1,000 applying in each case. Deposits cannot exceed $300,000 per taxpayer at any one time and are lodged with the Commonwealth Department of Primary Industries and Energy, with a fee of $20;

- Interest is paid at the short-term Government Bond on 61% of the deposit (the rest of the deposit is the proportion that would have been paid in tax had the deposit not been made). Interest on deposits can be automatically reinvested; and

- A withholding tax rate of 20% is paid at time of withdrawal. Taxpayers may withdraw a deposit at any time once 12 months have elapsed since the deposit was made. Deposits also become repayable on death or bankruptcy or where the taxpayer ceases to be an eligible primary producer.

Cash reserves are an essential component of a farm risk management strategy and considered extremely important by the farm sector. The build up of cash reserves is influenced by changes in commodity prices, seasonal conditions and the taxation system. Farm Management Bonds (FMBs) are aimed at assisting farmers in building up cash reserves for use in difficult financial circumstances. Farmers have a range of choices in disposing of available cash reserves, including: putting the cash in the bank or some other form of off–farm investment; spending on inputs which are 100% deductible; investing in on–farm capital equipment which is depreciable over a number of years; and putting cash in IED/FMBs. The combined tax saving and interest benefits make investments in the FMB scheme attractive relative to the listed alternatives.

From 1 October 1992, FMBs formed a part of the IED scheme. Changes were made to the scheme in late 1994 and are to be introduced during the 1994–95 financial year. Subject to this qualification, FMBs will have the following features:

- The maximum deposit for FMBs is $150,000 per taxpayer (forming part of the overall $300,000 IED limit) and farmers receive interest on the entire deposit;

- Only primary producers with taxable non-farm income of less than $50,000 are eligible to make FMB deposits and only $10,000 of non farm income can be deposited in FMBs;

- FMBs may only be withdrawn on the grounds that the depositor is experiencing serious financial difficulties because of:

  A significant fall in commodity prices (average prices received in year of withdrawal at least 25% lower than the average for the previous three years);

  Drought, disease, fire, flood or similar natural event;

  FMBs withdrawn at other times are treated as ordinary IEDs with the benefit of a higher investment component revoked.

  FMBs retrospectively revert to IEDs on retirement; and

- No withholding tax is payable on the withdrawal of FMBs.

A Drought Preparedness Investment Allowance

An investment allowance of 10% is to be introduced on 24 March 1995, providing the necessary Legislative amendments pass through the Parliament, for expenditure on:

- Fodder storage facilities;
- Livestock drinking water storages (including dams and tanks) and water conveyancing (including bore reticulation); and
- Minimum tillage cultivation equipment.

The investment allowance will cease on 30 June 2000. The proposed provision of an investment allowance, for investment in livestock water and fodder storage, water conveyancing and minimum tillage equipment, will encourage farmers to prepare for drought and maintain cash flows during drought periods.

The provision of reticulated bore water and other stored water is an important aspect of improving drought management. The ability to shift water closer to available feed is likely to cut farm costs and maintain the condition of livestock and pasture for much longer periods during drought, effectively reducing the impacts of land degradation resulting from pasture loss.

Landcare for Maintaining and Protecting the Resource Base

Under the National Landcare Program, communities are encouraged to set up locally based groups to plan, promote and implement sustainable land use practices. The Commonwealth provides assistance under this program for land, water and related vegetation projects. The program provides support for groups to combat land and water degradation, and achieve sustainable land use. It is also aimed at improving the skills in communities so that they can implement sustainable resource programs. Projects can cover a considerable range of local problems, including soil structure decline, waterlogging, salinity, stream bank erosion and deterioration in water quality.

The NLP also provides support for larger initiatives that address impediments to sustainable natural resource management at the regional level, and these initiatives are being integrated with measures under the Rural Adjustment Scheme.

The Rural Adjustment Scheme (RAS)

RAS can help eligible farmers improve the productivity, sustainability and profitability of their farms. The scheme also provides assistance for farmers who wish to leave farming. In addition, RAS gives support to long-term profitable farmers facing exceptional circumstances such as severe drought.

RAS is administered by State RAS authorities under guidelines issued by the Commonwealth.

The following measures are available under RAS:

- Grants for training and professional advice;
- Farm productivity enhancement measures (incorporating an interest subsidy of up to 50% of the cost of commercial finance);
- Re-establishment grants of up to $45,000 for farmers without prospects of long–term profitability who wish to leave the farm sector.

  Re–establishment grants totalling up to $75,000 are available in drought exceptional circumstances areas, along with immediate access to labour market programs; and
- Exceptional circumstances assistance (incorporating an interest subsidy of up to 100% of the cost of commercial finance).

In the case of re–establishment grants, a farmer must be assessed by the State RAS authority as not having prospects for long term profitability and must sell their farm. This grant is assets tested, with the re–establishment grant being reduced by one dollar for every dollar in assets the recipient retains after the farm sale in excess of $45,000. RAS also has specific regional initiatives.

The Farm Household Support (FHS) Scheme

FHS is a loan available to farmers to enable them to meet the living expenses of the farm family. It is paid fortnightly at the same rate as the Job Search Allowance. FHS is administered by the Department of Social Security on behalf of the Department of Primary Industries and Energy. FHS caters for the 'grey area' where farmers are not able to obtain further finance through financial institutions yet believe their property is viable. A two year loan with appropriate repayment terms can help in such situations.

If an FHS recipient sells their farm within two years of first receiving FHS, they may have nine months of their FHS payments converted to a grant. If an FHS recipient sells their farm within nine months of first receiving FHS, the balance of nine months of FHS payments is paid to the farmer as a grant. If an FHS recipient does not sell their farm, then the whole amount of FHS paid is treated as a loan.

To qualify for FHS, a person must:

- Be a farmer at least 16 years old;
- Be unable to access further commercial finance (proof of which is a 'certificate of inability to obtain finance' validated by a financial institution); and
- Be an Australian resident, currently living in Australia.

FHS is means tested. An income test (a married couple may earn up to around $19,000 pa in certain circumstances) and an off–farm assets test (net assets up to $163,500 for a married couple—and farm assets are excluded) applies. No work activity test applies.

In recognition of the structural problems in central and western NSW, which have been exacerbated by the current drought, the Minister for Primary Industries and Energy has extended the FHS grant period for FHS recipients in this area from the normal nine months to a maximum of two years.

The extension means that FHS recipients in these areas who sell their farms within two years of receiving FHS will not have to repay any amount of FHS received. Those FHS recipients in these areas who do not sell their farm within the required two year period will still have to repay any amount of FHS received.

The Welfare of Farmers in Extreme Drought

On declaration of drought exceptional circumstances, farmers and their families in the designated areas can apply for a Drought Relief Payment and for exceptional circumstances interest rate subsidies under the RAS. The Drought Relief Payment is a welfare payment designed to assist farmers affected by exceptionally prolonged and severe drought to meet basic family living expenses. It is administered by the Department of Social Security on behalf of the Department of Primary Industries and Energy.

The Drought Relief Payment is equivalent to the Job Search Allowance, includes a Partner Allowance and the Family Payment as applicable.

Drought Relief Payment recipients also receive a Health Care Card. Students from families in receipt of Drought Relief Payment have all farm assets excluded from the AUSTUDY assets test, and are not subject to a separate parental income test under AUSTUDY.

Drought Relief Payments will continue for six months after the end of the drought exceptional circumstances to provide a 'recovery period' for farmers.

To qualify for the Drought Relief Payment, a person must:

- Be a farmer at least 18 years old;
- Have a farm enterprise located in an area affected by drought exceptional circumstances (proof of which is a 'drought exceptional circumstances certificate' issued by the relevant State RAS authority); and
- Be an Australian resident, currently living in Australia.

Payments are subject to an income test (a married couple may earn up to around $19,000 pa in certain circumstances) and an off-farm assets test (net assets up to $163,500 for a married couple—and farm assets are excluded). No work activity test applies.

Farm Household Support recipients who meet these criteria may transfer to the Drought Relief Payment, with all obligations and payments under Farm Household Support suspended while they are in receipt of a Drought Relief Payment.

Continued Research Program

Commonwealth funds have been made available to 1997–98 to continue with a drought research program. Funds have been provided to the National Resource Information Centre (NRIC) in the Bureau of Resource Sciences (BRS) and the Land and Water Resources Research and Development Corporation (LWRRDC) to undertake programs of research aimed at minimising the effects of climate variability on agriculture and the natural resource base.

Three main priorities are to be addressed at a total cost of $5.013 million:

1 **Objective criteria for exceptional circumstances declarations**
In October 1994, the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) agreed on six core criteria for determining drought exceptional circumstances. These criteria are: meteorological conditions, agronomic and stock conditions, water supplies, environmental impacts, farm income levels and scale of the event. The Bureau of Resource Sciences will develop regionally sensitive scientific indicators for each of these core criteria to allow objective and consistent declarations across Australia.

2 **The effects of national and global climate variability on the sustainability of agriculture and the natural resource base**
NRIC will coordinate research with a focus on continental scale land use, interactions with climate shifts and variability, subsequent effects on sustainability and potential productivity of Australia's natural resource base, and interactions with land use policy.
Outputs will enable monitoring of resource status and will assist in policy development for sustainable resource use. Participation in expanded international programs in climate prediction and resource protection, such as those of the United Nations are also anticipated.

3 **Managing with climate variability**
This program is administered by LWRRDC and is based on multi–agency collaborative projects with a focus on delivery to farmers of techniques to assist with self reliant management. The program has recently been reviewed and three components identified as being of high priority for further research:

Climate forecasting—The objective of this program is to provide improved systems for weather forecasts and climate prediction based on development of global climate models. Recent research on the Southern Oscillation and El Niño phenomena has highlighted their importance in determining climate in Eastern Australia. Improved predictors based on better understanding of sea surface temperatures and their interactions with weather are now being developed.

Drought risk monitoring—This program has the objective of integrating climate and weather data with agricultural systems models to provide drought alert systems and production predictions for agriculture. The aim is to increase the benefit available from weather information by linking it to agricultural parameters such as plant-available-moisture and evapotranspiration indices. These will then be used to monitor seasonal conditions and provide alerts of impending crop and pasture failure, and resource management risks arising from reduced vegetation cover.

Decision support for farm risk management—The objective is to develop farm management systems designed to improve preparedness for drought. It is important for agricultural enterprises to choose production strategies that maximise income during favourable years, are robust in the face of climatic variability and enhance enterprise survival during poor years. This project will develop alternative management systems that provide self reliance, are user friendly to farm managers and contribute to sustainable resource use.

Conclusion

Drought policy includes the declaration of drought exceptional circumstances. Associated policies provide welfare relief to those severely affected and carry-on finance to long term viable operators of farm businesses. The policy caters for the key groups of farmers, from the autonomous managers to the non–viable. Measures encouraging productivity growth, the putting aside of financial resources for use during drought, farm build–up and regional adjustment together with skills training and drought research also provide the basis for a policy for post drought recovery and the move towards self–reliance.