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SUMMARY

The term "pasture" is used to refer to all plant communities which support domestic livestock except for annually sown crops. Pastures may therefore range from communities consisting primarily of native species to highly improved pastures, consisting entirely of sown exotic species.

The essence of pasture management is the manipulation of the species composition of a pasture to obtain and maintain a desirable species composition consistent with the overall management objectives for the particular pasture in question. Therefore it is important to clearly define the management objectives and to identify desirable species compositions before any particular pasture can be managed.

The likely economic conditions under which the grazing industry will be operating in the 1980's are briefly examined. A probable worsening of the cost/price ratio for animal products indicates that future pasture research should concentrate on devising low cost management systems rather than increasing pasture or animal production irrespective of input costs. Such systems must be based on a better knowledge of the autecology of important pasture species including native, naturalized and sown species and of their responses to a wide range of manipulations. This knowledge is also essential when the management objectives are other than animal production.

INTRODUCTION

The term "pasture" is commonly used in Australia to denote all plant communities which support domestic livestock except for annually sown crops. Even when the use of these plant communities is radically altered, for instance when they become part of a National Park and no longer support domestic livestock, they are usually still referred to as pastures. Some authors (e.g. Moore 1970) have objected to this broad definition on the grounds that it is too broad, covers too many different types of plant community and is confusing to grassland scientists outside Australia. However, I wish to use the term in this broad sense because the following discussion refers to the management of a broad spectrum of plant communities even though the types of manipulation may vary in different situations. The range of plant communities included extends from native pastures, composed primarily of indigenous species to highly improved pastures which require expensive inputs for their maintenance.

Rational management of any system is impossible without clearly defined management objectives. Traditionally, the main objectives of pasture management in Australia has been maximum animal production consistent with long term pasture stability but this is not the only objective. In recent years there has been an increasing amount of pasture land diverted to other uses such as National Parks which involve quite different problems of management. Those responsible for the management of these pastures have yet to really come to

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grips with their management objectives and so have not been able to devise appropriate management strategies (Sallaway and Lacey 1975). Pastures are also used in other situations such as reclamation after mining (Blandford 1965a, 1965b; Barr and Atkinson 1970), or in landscaping (Hagon et al. 1975; Anon. 1977). Pasture agronomists in the 1980's must be sufficiently flexible to cope with a wide range of management objectives and to devise appropriate management strategies.

The overall objective of pasture management is assumed to be animal production, either wool or meat, for the major part of this discussion. The two major considerations in this context are the management of the pasture species assemblage and the management of the animals to harvest the pasture and convert it into animal products (Lazenby 1967). The ultimate test of the effectiveness of the overall management of both plants and animals is the output of animal products in relation to inputs in terms of land, plant and animal management. Here we are primarily concerned with plant management aspects but the overall aim of the management system must always be kept in mind.

Ideally, pasture management is always concerned with producing a particular species assemblage on a particular piece of land and maintaining it. This principle applies to all pastures from native to highly improved. The particular species assemblage may vary throughout the year or from year to year with changing weather conditions or in different parts of the one paddock depending on soil, topography and animal grazing patterns. It is theoretically possible to envisage a realistic "ideal" species assemblage for every pasture situation and if this is not possible in practice it reflects a lack of knowledge of the species and the situation in question.

If pasture management objectives are defined in terms of the most desirable species assemblage for a particular situation consistent with the overall management objectives, then a knowledge of the population dynamics and the factors regulating populations of individual species is of great importance. Individual plant species vary widely in their reaction to environmental and management factors and in their usefulness to man and/or his domestic animals. Some of these factors can easily be varied for a particular piece of land while others are less amenable to manipulation.

FASHIONS IN MANAGEMENT

Australian pastures generally evolved under quite different ecological conditions from those which have existed since European settlement (Moore 1959; Whalley 1970). Accordingly, the original pasture dominants were poorly adapted to grazing by domestic livestock and had little capacity to respond to increased soil fertility. The discovery early this century that topdressing with superphosphate enabled the establishment of exotic clovers and high producing exotic grasses led to a revolution in pasture management. The term "pasture improvement" came to be synonymous with sowing exotic grasses and legumes and topdressing with the appropriate fertilizers to obtain maximum plant production in any particular region. Plant explorers scoured the world to find exotic species suitable for different areas (Hartley 1950; Hartley and Williams 1956) and intensive plant nutrition studies of "problem soils" led to significant advances in the knowledge of trace element deficiencies and how to correct them (e.g. Riceman 1950). The widespread plant introduction programs have occasionally also led to the introduction of species which have undesirable characteristics such as *Eragrostis curvula* on the Northern Tablelands of N.S.W. (Robinson 1979) and *Hyparrhenia hirta* on the Northwestern Slopes.

This "replacement philosophy" has now dominated the thinking of Australian pasture agronomists for nearly forty years. Griffith-Davies and Eyles (1965) outlined the areas of Australia suitable for the introduction of temperate exotic species and much effort has been expended in searching for species suitable for semi-arid, arid and the tropical parts of Australia. So concerned have agronomists been with searching for exotic species that virtually no effort has been expended in surveying the Australian native species (Whalley 1970).

A corollary to the all-pervading "replacement philosophy" is that most Australian pasture agronomists think only in terms of pasture seeding, fertiliser application and stocking rate when considering the manipulation of species assemblages. These are not the only options open to pasture managers and in many situations they may be inappropriate for agronomic, economic or other reasons. There are signs that the fashions in pasture management are changing and more interest is being shown in the possibility of managing native and natural pastures. Even in more humid areas such as the Northern Tablelands of N.S.W. graziers are expressing more interest in the management of native and natural pastures because of the high costs involved in the establishment and maintenance of improved pastures and the uncertainty of any one type of live-stock production producing sustained economic returns (Robinson 1979). Pasture agronomists in the 1980's must be aware of these changing fashions in pasture management and be flexible and innovative in their outlook and not be constrained by the traditional "replacement philosophy" and the approaches appropriate to it.

PRODUCTIVITY PROSPECTS FOR THE 1980's

The term productivity is often used to describe the gross output of a process either as a quantity of product or as its cash value, or more correctly to describe the ratio of outputs to inputs, again in quantities or in cash value terms. If pastures in Australia are generally managed with livestock production as the main objective, then the total volume of livestock production is a measure of the production of these pastures. The total volume of live-stock production can be compared with the total volume of inputs to give the productivity or, more readily, the cash value of the production is compared with the cash value of the inputs. Increased total production means little if the prices paid for the extra inputs equals or exceeds the prices received for the extra product.

Any discussion of productivity prospects and research challenges for the 1980's must be based on assumptions concerning general economic conditions during the next ten years and beyond. I assume that the present trends in these conditions will continue but abrupt changes in political or economic policy can easily render this assumption invalid.

There has been a steady increase in the total rural production in Australia over the last twenty years (Fig. 1). The fluctuations in the volume of crop production result from changing seasonal conditions while the increase in volume of livestock products has been more uniform. The increased animal production presumably results from further land clearing and the gradual spread of improved technology through the pastoral community.

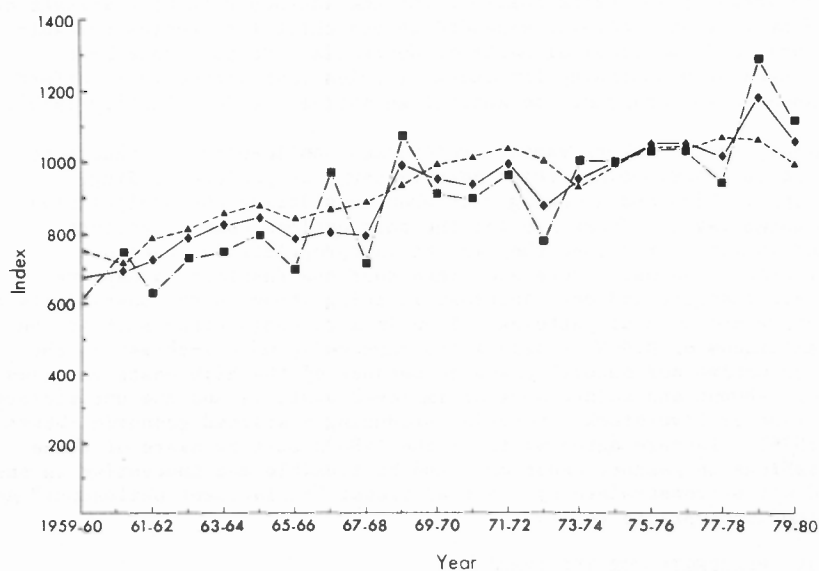


Fig. 1. Indexes of the volume of crop (■—■), livestock (▲—▲) and total (◆—◆) Australian agricultural production for the years 1959 to 1980. Values are indexed to 1974-75 = 1,000 (Source, B.A.E. 1979).

The changes in indexed prices paid and prices received by Australian farmers over the last 20 years (Fig. 2) show that they have been subjected to a cost-price squeeze and deteriorating terms of trade (Schapper 1979). The prices paid for management inputs have generally risen faster than prices received for agricultural products (Fig. 2). As an example, in 1950-51, one bale of wool would have purchased 20 tons of superphosphate whereas in 1978-79, the same bale of wool would only purchase 5 tons (Schapper 1979). It seems that the cost-price squeeze is likely to continue.

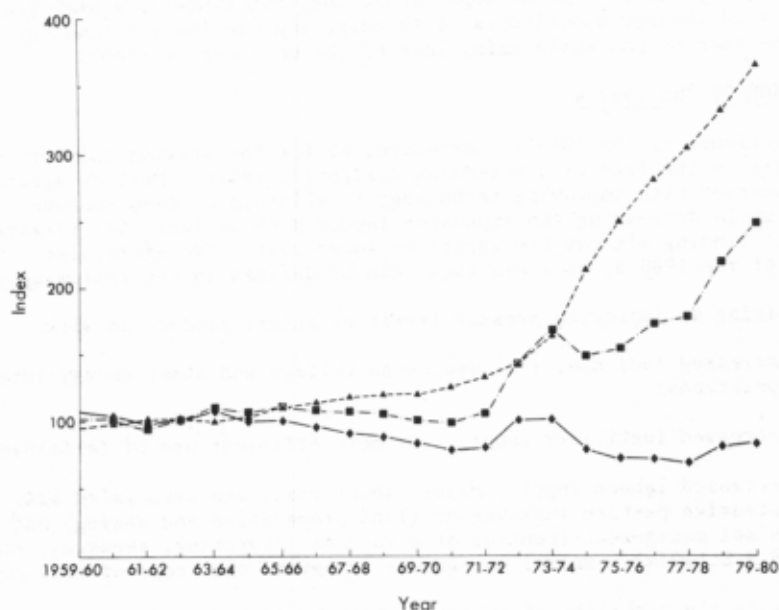


Fig. 2. Indexes of the prices received (■—■) prices paid (▲---▲) and the ratio of prices received to prices paid (◆—◆) by Australian farmers for the years 1959-1980. Values are indexed to the base average 1960 to 1963 = 100. (Source, B.A.E. 1979).

The last ten years have seen a very rapid rise in the price of oil and there is every reason to believe that this rise will continue. Hughes and Mesarovic (1978) predicted that the world price of oil would rise to about \$30 per barrel by the year 2,000 whereas in mid-1979 it was already about \$20 per barrel; well ahead of their predictions.

The most rapid relative change in the prices paid and prices received in the rural sector occurred during the period 1973-1977 (Fig. 2). This followed the very rapid increases in the price of oil imposed by the OPEC nations in 1973. It is difficult to predict the effects of the projected continued rise in oil prices on the cost-price ratio of Australian animal products because prices are so dependant on international economic activity (B.A.E. 1979). The data presented in Fig. 2 would seem to indicate that sudden increases in oil prices have an adverse effect on the cost/price ratio but that the recent, more regular increases have had much less effect.

Individual pastoralists can do little about the prices received for their products and so they have essentially three strategies to cope with a worsening cost/price ratio. The first is to increase their volume of production by acquiring more land and increasing the size of their enterprise. Alternatively, they can identify those items of input where the cost rises have been greatest and either find cheaper substitutes or thirdly, improve their technology to maintain the same output while using less of the more costly inputs.

THE CHALLENGE OF THE 1980's

The challenge of the 1980's, therefore, is for the grazing industry to remain viable in the face of a worsening cost/price ratio. Pasture agronomists must be concerned with improving technology to maintain or even improve production while decreasing the expensive inputs such as fuel, fertilizers and labour or of finding alternative inputs of lower cost. Therefore, the challenges of the 1980's, as I see them, can be defined in the following terms.

- (1) Maintaining or improving present levels of animal production with:
 - (a) decreased fuel use, i.e. decreased tillage and other energy-intensive operations;
 - (b) decreased fertilizer input, i.e. more efficient use of fertilizer;
 - (c) decreased labour input. Major labour costs are associated with intensive pasture improvement (land preparation and sowing) and with animal management (control of parasites, crutching, shearing, etc.) (B.A.E. 1974). Animal management is beyond the scope of this paper.
- (2) Increasing the stability of pastures, both humid and arid zone to maintain production in the future through:
 - (a) better knowledge of the population dynamics under grazing of individual pasture species, both annual and perennial;
 - (b) better knowledge of the autecology of important pasture species, both desirable and undesirable, and including native, naturalized and sown species;
 - (c) better knowledge derived from both (a) and (b) above of how to manipulate the species composition of pastures without expensive clean cultivation and reseedling. This manipulation requires a detailed knowledge of secondary plant succession and can be applied to all pastures from native to highly improved.
- (3) Increasing the managerial skills of pasture managers (graziers) within the context of (1) and (2) above. Pasture research surely has the greatest backlog of unapplied (or perhaps unapplicable) results of any field of research. If graziers are to manage populations of native, naturalized and sown species, they must be able to recognise the individual species. This facet of education alone represents a major challenge to extension agronomists, many of whom themselves find native and naturalized species difficult to recognise.

PROSPECTS FOR TECHNOLOGICAL ADVANCE

I see the major prospects for technological advance in terms of the major challenges of the 1980's outlined above. Some of these challenges are more

likely to yield useful results than others and so perhaps are worthy of more research effort. I do not consider increasing pasture production per unit area irrespective of the management inputs involved an appropriate research aim for the 1980's in Australia.

Use of Fuel

The major fuel costs of improved pastures in the establishment phase. Clean cultivation, seedbed preparation and sowing are energy and labour intensive processes and much research effort has been invested in the past in reducing these costs. Chemical seedbed preparation, sod seeding and aerial seeding are techniques which have been developed to reduce the cost of pasture establishment (Breakwell and Jenkins 1953; Johnson 1964; Campbell 1968; Hutchings 1972; Dowling and Smith 1976) and there seems to be little prospect for further spectacular advance along these lines. The only other avenues for reducing the fuel costs of pasture establishment, are to increase the interval between pasture reseeding (longer lived improved pastures) or to avoid it altogether by using pastures composed of native and naturalized species.

Use of Fertilizers

With the passing of cheap superphosphate in the early 1970's, attention has been focussed on ways of reducing previously lavish fertilizer recommendations. This type of development has followed four main lines and offers scope for further research, particularly with respect to using fertilizer applications to manipulate the species composition of a pasture.

The first involves matching the fertilizer usage more exactly with soil deficiencies (Osborne *et al.* 1977) and involves detailed soil surveys (e.g. Spencer and Barrow 1963). Perhaps the best example is the substitution of gypsum or elemental sulphur on soils where the response to superphosphate is attributable to its sulphur content rather than phosphorus. While agronomically successful on soils such as those derived from basalts on the Northern Tablelands of N.S.W. (Weir *et al.* 1963; Robson and Loneragan 1978) I understand that difficulties have been encountered with the safety aspects of spreading elemental sulphur by air. Further research into the effects of elemental sulphur on soil microbial populations and its incorporation into plant material is needed.

Where substantial quantities of superphosphate have been applied in the past in ley farming systems in southern Australia, recent research indicates that superphosphate application can be omitted in the pasture phase (Ayres *et al.* 1977; Osborne *et al.* 1977). Provided sufficient superphosphate is applied in the cropping phase to maintain adequate soil phosphorus levels, no decline in either crop or pasture productivity occurs. Further research is necessary on other soils with long histories of fertilizer application to determine the minimum levels necessary to maintain productivity.

With aerially sown improved pastures in southern Australia, the native grasses at first make some contribution to the sward. Under conditions of high fertility and grazing pressure, they are unable to compete with the introduced clovers and grasses and eventually disappear (Donald and Williams 1954). Native species on the Northern Tablelands of N.S.W. do not disappear so easily (Whalley *et al.* 1978) and so called natural pastures composed of both native and naturalized species can be maintained with lower rates of superphosphate than those necessary for the establishment and maintenance of highly improved pastures (Hartridge 1979). Fertilizers (usually superphosphate) with or without

the addition of a high producing pasture legume is simply applied to native pasture and with grazing, subsequent species composition changes occur to produce a natural pasture (Robinson and Lazenby 1976; Whalley et al. 1978). This practice is also common on the North Western Slopes of N.S.W. However, very little research has been done on the effects of such fertilizer application either in terms of changes in species composition of the pastures, the relative grazing value of the different species present after fertilization, or the increases in animal production which can be obtained by this practice. Some work has been done on the Northern Tablelands and indications are that topdressing natural pastures with the addition of white clover can lead to substantial increases in animal production approaching the levels obtained with improved pasture but without the cultivation and other costs involved in improved pasture establishment (Robinson and Lazenby 1976; Whalley et al. 1978). In this respect, the grazing community has moved ahead of the agronomic research establishment and more research into the effects of topdressing natural pastures is urgently needed.

A third approach is to use species and varieties which are efficient in terms of their nutrient responses, i.e. they respond to low fertilizer levels. There are marked differences in the responses among both grasses and legumes to different levels of nutrients (Wilson and Haydock 1971; Jones 1974; Andrew and Johansen 1978). It seems strange to me that this work has developed in the absence of detailed studies of the species changes which occur in native pastures following fertilizer applications. Different native species differ markedly in their responses to increased soil fertility (Robinson 1976; Harradine and Whalley 1978) and the easiest place to detect those species with the highest responses is in comparisons between fertilized and unfertilized pastures. There also appear to be marked differences in the efficiency of nitrogen use between some C_3 and C_4 species (Brown 1978).

Studies of nutrient cycling in grazing pastures (e.g. Till and May 1971; Helyar 1976) can perhaps reveal where the major nutrient losses occur and suggest means of preventing or at least reducing these losses. The major avenues for loss are (a) immobilization (b) losses through leaching or volatilization (c) export in animal products (Helyar 1976; Till 1976) 9d) redistribution by grazing animals within a paddock (Hilder 1966). The relative magnitude of these avenues differs between nutrients. Under certain circumstances, redistribution within the paddock may be the most important of these processes with respect to the efficient use of applied fertilizers (Hilder 1966). Therefore, any studies of nutrient cycling in grazed pastures must include the grazing behaviour of the animals involved in order to be realistic. Nutrient cycling studies are expensive but perhaps they can lead to altered management procedures which will increase the efficiency of fertilizer applications.

Population Dynamics of Pastures

Little is known about the population dynamics of individual species in grazed pastures of any type (Hodgkinson and Williams 1979) and yet such knowledge is at the heart of pasture management as I see it. Increased pasture stability, particularly of perennial pastures, means improving the balance between longevity and recruitment of individual plants.

If density and species composition are to remain constant with time, then each adult must be replaced on its death by one seedling (Harper 1977). Recruitment of perennials seems to be markedly episodic for some species (Hodgkinson and Williams 1979) but little or no information is available for most pasture species either annual or perennial. Demographic data is somewhat tedious to collect but it is an area where the prospects of obtaining useful information are very good for the 1980's.

Plant Succession and Pasture Management

The traditional view of secondary plant succession is that following a disturbance, a sequence of species assemblages occurs leading to a plant community capable of reproducing itself indefinitely. This view owes its origin largely to Clements (1916) but has been subsequently modified by many authors. It is now recognised that most of the phenomena of succession can be explained in terms of the properties and characteristics of the individual species involved at various stages in the succession. This approach to succession has recently been formalised by Noble and Slatyer (1979) with the identification of characteristics of individual species which are important for the maintenance of those species in particular plant communities. They have named these characteristics "vital attributes" and have grouped them into three main kinds relating to:-

- "(1) The method of arrival or persistence of the species at the site during and after the disturbance
- (2) The ability to establish and grow to maturity in the developing community
- (3) The time taken for the species to reach critical life stages."

If pasture management is viewed as a "directed succession" where the manager modifies various aspects of the environment to direct the species composition in a desired direction, then the vital attributes of the desirable and undesirable species are of critical importance. Noble and Slatyer (1979) have only dealt with broad aspects of the approach although an example of how it can be used to predict the results of management in a particular situation (high and low intensity fires at three different periods of the year in Northern Australia) is given in Lacey *et al.* (1979). There is no real reason why this approach cannot be applied to predicting the results of management practices designed to increase the longevity of improved pastures. It would appear to be very valuable in the selection of those aspects of the autecology of individual species to be studied in particular situations in order to predict their responses to management. To date this selection has depended on the intuition or the prejudices of the researcher concerned (Whalley 1970; Taylor and Whalley 1976).

Grazing animals have marked effects on pastures and these have recently been reviewed by Watkin and Clements (1978). When the overall objective of pasture management is animal production, the management inputs can never be considered in isolation from the animals which are to graze the pasture. The grazing animals, the end products of the management objective, are themselves a management input.

While grazing animals have obvious effects on the species composition of pastures, the deliberate use of grazing animals as a means of altering the species composition in a desired direction on a whole farm basis is a far

more difficult exercise. The majority of rotational or deferred grazing experiments in the past in Australia have been aimed at devising grazing systems which optimize feed supply and its utilization by the animal (Myers 1972). Very few accounts exist where grazing animals have been used to produce specific, desired changes in botanical composition.

Shugart and West (1977) and Shugart and Noble (1980) have developed computer models which predict changes in plant populations with time of 1/12 ha plots of forest. These models follow the recruitment growth and death of each individual plant growing on the simulated plot. The changes in population with fires of different intensity and at different times in the life cycles of individuals growing on the plot or of the effects of other management inputs can be simulated (Shugart and Noble 1980). This type of model can surely be adapted to follow changes in simulated pasture plots and would be an exciting tool for the development of systems of pasture management.

The development and use of such models would have several advantages. It would highlight the gaps in autecological knowledge of pasture species which are critical in the management of those species. More importantly it would enable complex management plans (involving say fertilizer applications, certain grazing strategies and controlled burning) to be tested cheaply and quickly. In this respect they would be much more useful than production models such as those developed by Vickery and Hedges (1972) and Smith and Williams (1973). Population computer models of successional changes in pastures and the autecological research they would generate would seem to me to be an important prospect for technological advance in the 1980's.

Pastures and Cropping in the 1980's

There seems to be a marked potential for an expansion of cropping activities under rain-fed conditions in Australia (McWilliam 1979). Ley farming systems have long been used to maintain soil fertility and structure in the subterranean clover/Wimmera ryegrass belt of southern Australia (Cornish 1949; Donald 1960). Any significant cropping expansion in these areas means a shortening of the pasture phase and more research is necessary on how to obtain the maximum soil therapy with the minimum time under pasture.

North of this belt in N.S.W. there is a need for information about how to manage the pasture phase for maximum soil therapy. Lucerne is the only widely used sown species in this area and on suitable soils the management of grazing lucerne and its integration into a ley farming system is well established (Peart 1968; Brownlee 1973). On soils unsuitable for lucerne, no suitable sown species exist and perhaps agronomists should learn more about secondary plant succession after cropping and try to devise management techniques which will hasten the development of a perennial native pasture.

In favourable seasons, the wheat belt tends to extend into more marginal lands and such an extension has occurred in northern N.S.W. since 1976. This cropping tends to be abandoned after a run of poor seasons and the problem is then how to return the farmland to pasture. Again, the best prospect seems to be a return to perennial native pasture but little information is available on succession following cropping. The problem is perhaps similar to that of the regeneration of perennial native pasture after overgrazing and depends on the episodic nature of the recruitment of these species (Williams 1977).

ADOPTION OF TECHNOLOGY

Australian graziers are quick to adopt a technology that is simple to apply and which produces a clear economic advantage. An example is the rapid increase of aerial spreading of superphosphate and white clover seed on the Northern Tablelands in the 1950's and 1960's. This technique was pioneered by a grazier Mr A.S. Nivison of "Mirani" near Walcha; not by a pasture agronomist (McDonald 1968). Many pasture management recommendations which have not been adopted so widely either require a high capital outlay and are beyond the financial capabilities of many graziers or are of doubtful economic value.

If, as I suggest, advances occur in the 1980's in the techniques of managing pasture species assemblages, then problems in agricultural extension are inevitable. Improved management techniques are unlikely to result in spectacular increases in pasture production in the next decade and perhaps such increases are undesirable. Rather, improved management would result in decreased costs for the same return or increased stability of the pasture system in the long term. Such techniques may be difficult to sell to some graziers.

It is impossible to manage a complex pasture species assemblage unless the manager is able to recognise the important individual species present. Many graziers, at least on the Northern Tablelands and I would suspect elsewhere, are unable to recognise more than a few of the important species that comprise their pastures. Many research and extension agronomists have the same inability. An opportunity exists, therefore, for the education of these people but this education will only be successful if more knowledge is available about the species that they are being taught to recognise. In 1977, a series of five one day workshops on the recognition of native grasses were held at different centres on the Northern Tablelands. The response and interest shown by graziers was very encouraging and the major deficiency was a lack of knowledge about the responses to manipulation and the value for grazing of the species under study.

CONCLUSIONS

The theme throughout this paper is that pasture management, as distinct from animal management, is always concerned with the manipulation of an assemblage of plant species. The objectives of the management must always be interpreted in terms of an "ideal" species assemblage before any pasture can be properly managed. The most important techniques which have been used in the past in the manipulation of species composition are pasture seeding, fertilizer application and stocking rate. Additional techniques are necessary for pastures where these methods have not been successful as in semi-arid and arid Australia or where the high cost of land preparation relative to returns makes pasture seeding unattractive.

The 1980's are likely to bring a continuation of the cost/price squeeze for Australian graziers. Therefore the major direction for pasture research should be in devising low cost management systems even for the higher rainfall regions. Such systems must be based on a better knowledge of the autecology of important pasture species, including native, naturalized and sown species and of their responses to a wide range of manipulations. This knowledge is also essential when the management objectives are other than animal production.

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