Grasslands, grazing animals and people — How do they all fit together?

R.D.B. WHALLEY
Botany, School of Rural Science and Natural Resources, University of New England, Armidale, New South Wales, Australia

Abstract

The view of pastures as a crop to be selected, sown, grown and harvested by grazing animals was common among scientists, government agency staff and livestock producers during the 1960s. Consequences of this view include the search for 'magic bullet' pasture species and the indiscriminate introduction and widespread testing of introduced germplasm in Australia. A number of serious environmental weeds have resulted. Another consequence was the almost complete dependence on cultivation, sowing, fertiliser application and herbicides as the only means of manipulating species composition in pastures.

The view that both the manager and the livestock are part of a complex grassland ecosystem has been gaining acceptance in recent years. The goals and perceptions of the manager as well as the activities of the livestock affect the functioning of this ecosystem in many ways. Further important consequences of this change in attitude have included the recognition of the power of grazing animals in manipulating the species composition of grasslands and a more sustainable approach to the management of grazing lands.

Introduction

There has been a quiet revolution over the last 10 years or so in the higher rainfall zones of temperate Australia in the way in which livestock producers view themselves, their grazing animals and the grasslands that provide their livelihood. The essence of these changes involves the realisation that a pasture is much more than a crop to be harvested by grazing animals but is a complex ecosystem of which the manager and the grazing animals are both parts. These changes are having dramatic effects on the livestock industries and many people are wrestling with the problem of how to apply the principles of grassland ecosystem management to a wide range of conditions, including the very extensive grazing industries in the north. The nature of these changes is best illustrated by going back a little over 30 years and comparing the approaches used then with more recent developments.

Correspondence: Dr R.D.B.Whalley, Botany, School of Rural Science and Natural Resources, University of New England, Armidale, NSW 2351, Australia. e-mail: rwhalley@metz.une.edu.au

Pasture as a crop

Lazenby (1967) viewed the sequence of events in pasture development as links in a chain (Figure 1) starting with the choice of species and cultivars through pasture establishment, pasture growth, pasture utilisation and an economic evaluation of the whole process. This approach is very much the same as growing a crop. The crop is chosen, sown, nurtured and finally harvested. In the case of the pasture, the animals do the harvesting and they are then harvested to result in various animal products. Lazenby's paper was specifically written for the Northern Tablelands of NSW but the attitudes illustrated were pervasive throughout Australia and have coloured the thinking of producers, government agency staff and academics for many years.

Great emphasis was placed on maximising pasture growth. In addition, any of the herbage mass not used by animals was considered wasted and consequently the harvesting technique was poor if this amount was large. However, there was a clear recognition that pasture growth depends on many factors including rainfall events and temperature, and so fluctuates widely both within and between years, whereas the pattern of feed requirements by grazing animals at different stages of their life cycles is much more predictable. The problem of matching feed availability and feed demand (both with respect to quality and quantity) was very much a part of how to manage the crop so that the 'wastage' was minimised while the animals' feed demands were met. This matching is obviously very difficult in regions with strongly seasonal rainfall.

If, in the course of aiming for high levels of utilisation through sequences of good and bad seasons, the pasture became degraded, it was simply resown.

Emphasis on limits to production

The strong emphasis on limits to production gave rise to a directional pasture production model with species and cultivars on the top left hand side leading through pasture production to herbage yield (Lazenby 1967; Figure 2). Factors affecting herbage yield, some of which are manipulable and some of which are not, are also listed. There is a strong emphasis on species and cultivars, and pasture establishment whereas other factors are simply listed. Some herbage is shown as lost by frosting, trampling and decay leading to the proportion of herbage eaten by the animal. The final animal production is affected by the class and breed of livestock and the quality of the grazed herbage. It is clear from Figure 2 and from the text (Lazenby 1967) that any herbage not eaten by animals was considered wasted.

Water availability

Lazenby (1967) recognised the fundamental importance of temperature, light energy and water for driving pasture production. Long-term rainfall average, whether it was distributed in the warm season or the cool season, affected the selection of species and cultivars for sowing in the pasture 'crop', and the areas in Australia which were suitable for pasture development according to this approach were delineated. Droughts were considered as exceptional circumstances rather than an intrinsic part of the ecosystem.

Consequences of this approach

The concept of pastures as a crop to be sown, grown and harvested has had a number of consequences both for higher rainfall and the semi-arid and arid parts of Australia. These consequences are different for different localities but are very firmly entrenched in the way many farmers consider their pastoral operations and how they manage their enterprises. Three of these consequences are:

(1) The search for species and cultivars

The belief that new 'magic bullet' pasture species capable of solving the problems of a region can still be found and sown is surprisingly strong among some producers and government agency staff. This belief persists despite widespread evidence of the problems associated with many deliberate plant introductions in the past (*e.g.* Humphries *et al.* 1991; Lonsdale 1994). New cultivar development certainly has a place but the indiscriminate introduction and widespread uncontrolled testing of new germplasm is hopefully an activity of the past.

(2) Modification of species composition

Increasing the abundance of a species. The perception is still common that, if a desirable species is either of low abundance or is not obvious in a pasture, the only way to increase it is to sow it either by some form of direct seeding or by ploughing up the whole area and resowing the pasture.

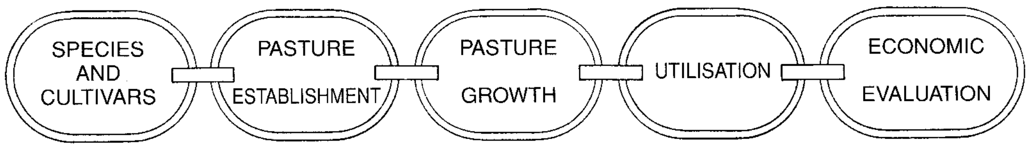

Figure 1. Diagrammatic representation of stages in pasture production (Lazenby 1967).

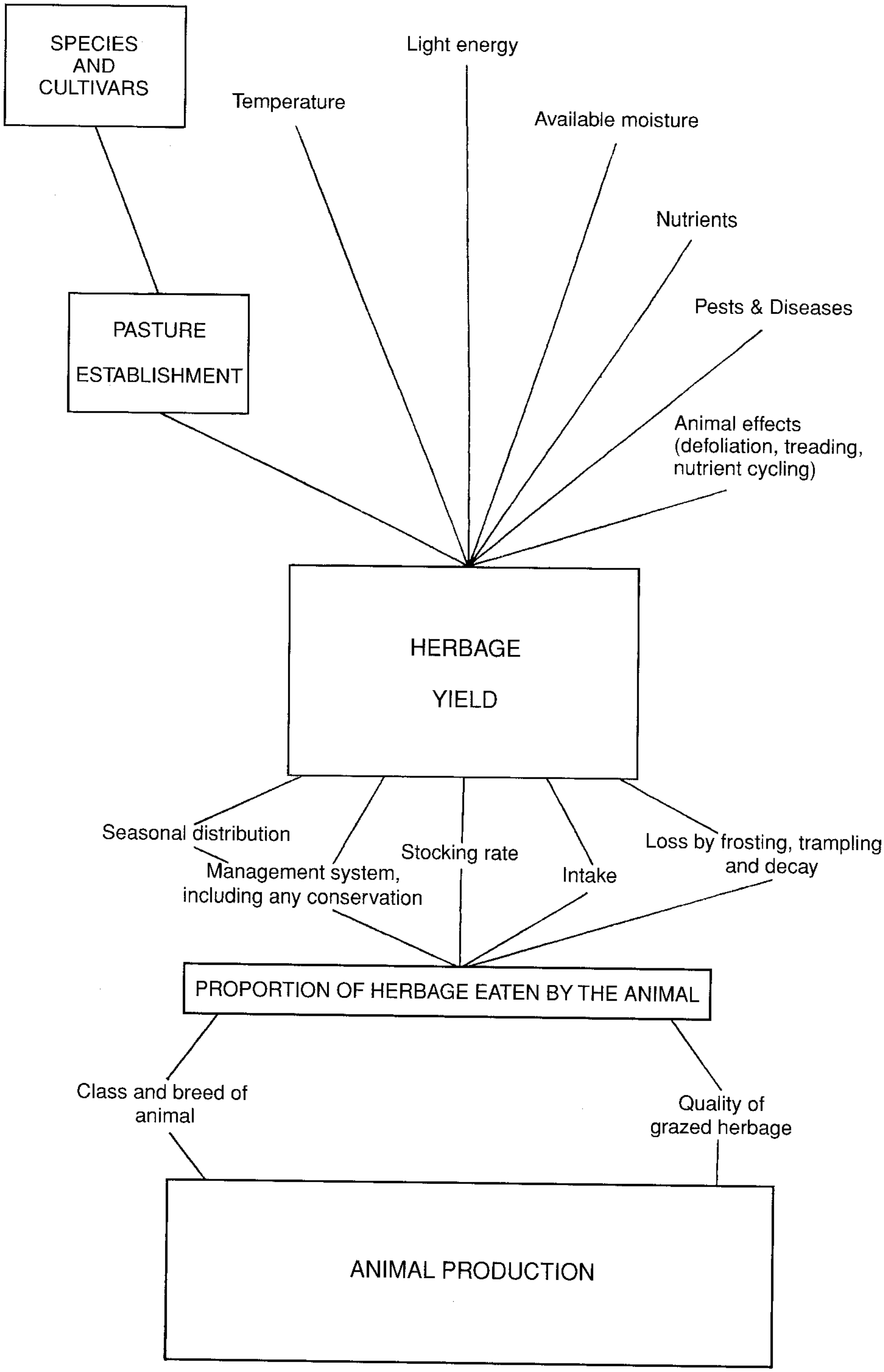

Figure 2. Factors affecting pasture production (Lazenby 1967).

Decreasing the abundance of a species. If a species has known undesirable characteristics for livestock production (*i.e.* it is a weed), the perception is that it must be sprayed, and if the right herbicide is applied at the right time, the weed will disappear.

(3) Approach to droughts

The 'average' rainfall was often thought of as the normal situation for a district and droughts were a recurrent problem that must be combatted and not an intrinsic part of the ecosystem. The ready availability of various forms of drought assistance in the 1960s encouraged this perception which still persists despite all the evidence to the contrary.

Grasslands as functional ecosystems

The view of grasslands as ecosystems with all the living parts interacting with each other and with the non-living parts, and that such ecosystems can be managed to result in saleable animal products, has been gaining strength rapidly over the last 10 years or so. This view is exemplified by the model in Figure 3 which has been modified from one originally devised by Dean Graetz of CSIRO at Deniliquin and first published by Harrington *et al.* (1984). Three important aspects set it apart from the Lazenby (1967) model. These are that: it is not linear but includes feedback loops; the manager is an integral part of the whole ecosystem; and the animals are part of the grassland system. It is impossible to deal with the complexity inherent in this model in a short paper, so I want to highlight several aspects that are vastly different from the Lazenby (1967) model.

Note that climate is the overall driving function of the whole grassland manager/ecosystem (Figure 3). For climate, the two most important variables are rainfall and temperature. The effect of these on the plant-animal-soil ecosystem and the animal products is modified by the manager's decisions, some of which are shown in the box on the right hand side of the model. The manager is shown as monitoring 3 important aspects of the system. These are the plant-animal-soil part of the ecosystem, the animal products and the climate itself. How this monitoring is translated through to the manager's decisions is affected by a number of powerful influences.

The first of these is the manager's perceptions, which relate to how the manager views the whole ecosystem in the first place. For instance, if a manager perceives his pasture plants as a crop to be harvested, managerial decisions will be vastly different from those resulting from a perception of grasses as components of a complex ecosystem. Another example is that a manager's perception of the climate on the Northern Tablelands might be coloured by the rainfall received during the 1950s. I have heard farmers say that it will be great when we stop having droughts and the seasons get back to 'normal'.

The perceptions of the items monitored are very strongly affected by the farmers' goals. For instance, the monitoring may be translated into certain managerial decisions by a farming couple in their mid- to late 40s with several children with high education expenses. Compare the decisions the same couple might make in their early 60s if their children have shown no interest in carrying on the family farm. The couple are essentially in a holding operation until the final decisions must be made about the future of the property. There are other outside influences which affect the translation of the farmers' monitoring into managerial decisions and actions.

The air-soil interface

The air-soil interface is critical to the operation of grassland ecosystems. Some organisms such as the manager and the livestock usually stay on the air side of this interface but there are many others whose domain stretches across it. Their activities are critically affected by the condition of the interface, and they, in turn, modify it by their activities. Other organisms critical to the functioning of grassland ecosystems spend their entire lives beneath the soil surface.

The two most important functions of the interface are the transfer of rainwater from above ground to below ground, and gas exchange between the air and the soil atmosphere. The gases of most concern are oxygen, carbon dioxide, and water vapour, particularly when evaporation occurs from the soil surface. If the soil surface is in poor condition, infiltration of rainwater is restricted and runoff can occur before the soil is saturated, leading to surface erosion and a subsequent shortage of soil water for plant growth. A surface seal can also lead to limited gas exchange with anaerobic conditions

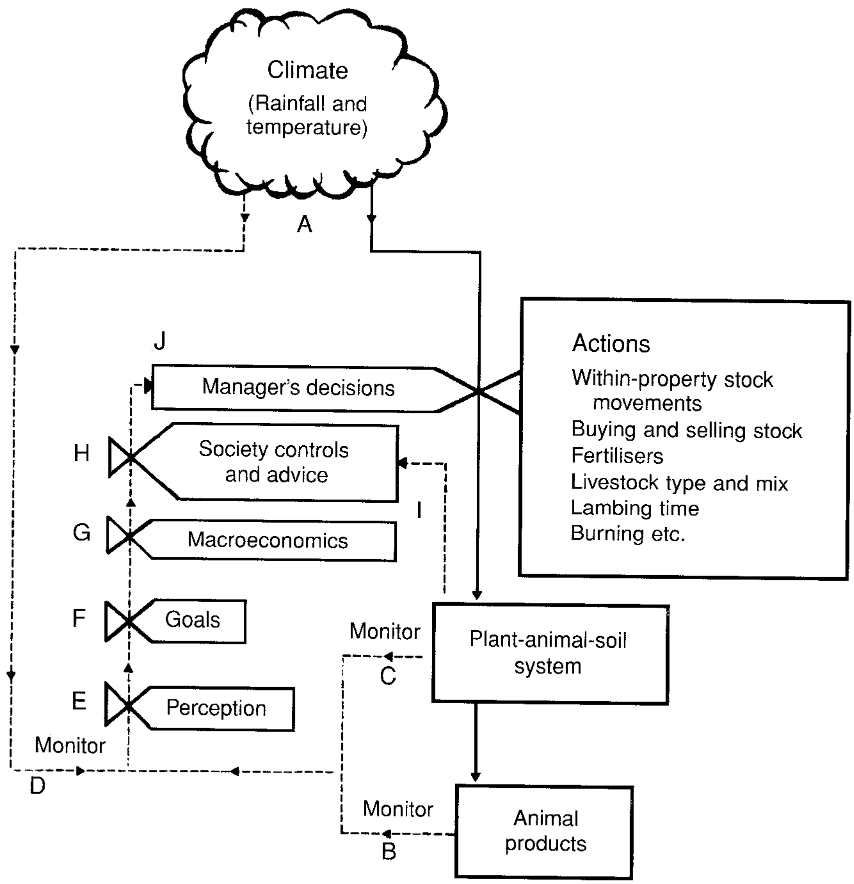

Figure 3. A grassland management paradigm (adapted from R.D. Graetz, unpublished data).

in the root zone and consequent restricted rooting depth and plant growth and/or changes in grassland species composition. With evaporation from the soil surface, the movement of water upwards can lead to the accumulation of soluble salts at the surface and subsequent changes to the functioning of the ecosystem.

The importance of the above-ground parts of plants for animal production is obvious but less obvious are some of the functions of plant roots which may directly or indirectly affect the condition of the soil surface. There is a continual turnover of the roots of grasses, and when the roots die, they leave channels that assist in the infiltration of water into the soil. The deeper the roots of the grasses, the deeper are these channels in the soil and the better the infiltration rates. Furthermore, dead roots provide an energy source for many soil organisms associated with mineral cycling in the soil, and the availability of minerals to the plants.

Many small animals are active both on the surface and within the surface layers of the soil. These include ants, earthworms, dung beetles and many meso-fauna species that transport organic material from above to below ground. All of these activities disturb the soil surface and lead to increased water infiltration rates and rates of gas exchange. These activities also increase the rates of nutrient cycling by the increased decomposition rates of organic materials once they are below the soil surface.

Animals as components of grassland ecosystems

Large and small herbivores do far more than simply harvest the plant material produced in a grassland ecosystem. Again, it is not possible in a short paper to deal with all these interactions, so I want to concentrate on several aspects that are completely neglected in the Lazenby (1967) model.

There are 2 sources of energy for the critical populations of small animals and micro-organisms that live at or under the soil surface. These are litter from the above-ground parts of plants and dead roots underground. Litter decomposition rates have been measured in many plant communities and the usual methodology is to place nylon bags of litter on or just under the soil surface and measure the disappearance rates (*e.g.* Chilcott 1998). However, the litter in grasslands, particularly native grasses, can remain standing for a long time and be unavailable to these organisms. Any process that breaks the litter off and lays it down flat will make it available and improve the condition of the soil surface.

Domestic livestock have dramatic effects on these 2 sources of energy depending on the grazing management. If an area is continually grazed with a high level of utilisation of the herbage produced, as recommended by Lazenby (1967), the individual plants of most species are frequently defoliated and the root system development is reduced (Harradine and Whalley 1981; Earl 1998). The energy supply for the soil surface and below-ground organisms is therefore severely curtailed. On the other hand, a short period of grazing with high animal density followed by a long period of rest will result in the standing litter being trampled down and becoming available to the surface dwellers, and root pruning of the living plants providing dead root material as an energy source for the underground organisms (Jones 2000). The surface litter also reduces raindrop impact on the soil surface and reduces surface sealing.

A short period of high animal density can be timed to coincide with critical periods in the life cycles of groups of pasture plant species such as seed fall. The result is that much of the seed is trampled into the ground and rapidly incorporated into the soil seedbank and is then largely out of range of seed predators such as ants (Lodge and Whalley 1985).

Long-term set stocking can result in soil compaction, and reduced infiltration rates irrespective of the stocking rate (Greenwood *et al.* 1997) and can also lead to undesirable changes in species composition (Hutchinson *et al.* 1995).

The important point is that grazing animals are far more than harvesting machines but are an integral part of the grassland system. Management decisions including animal density, length of the grazing and rest periods and livestock species will have effects on the animal-plant-soil system and the manager must be aware of, and take account of, these effects when making decisions.

Importance of plant species composition

The most valuable species from the animal production point of view are those with a high proportion of palatable green leaf. Such species usually have the ability to respond to added nutrients although the available data are not very clear (Lodge 1979). With leafy species, the most important factors affecting the nutritive value of these green leaves are (Jones 1995): stage of growth; age of the plants; and soil nutrient status.

That these 3 factors are far more important than the grass species, provided the proportion of green leaf is high, has been known for many years (McClymont 1969) but has often been disregarded. Jones (1995) has emphasised the importance of plant age and soil nutrient level with some simple data (Table 1).

Table 1. Crude protein percentages of *Elymus scaber, Microlaena stipoides, Themeda australis, Phalaris aquatica* and *Paspalum dilatatum* collected on the same day (from Jones 1995).

Species	Plant age	Status	Crude protein (%)
Elymus scaber	6 months	Fertilised	30.1
Shannon microlaena	10 months	Fertilised	26.9
Wakefield microlaena	10 months	Fertilised	22.6
Griffin microlaena	10 months	Fertilised	25.3
Themeda australis	Several years	Fertilised	12.0
Phalaris aquatica	Several years	Unfertilised	7.7
Paspalum dilatatum	Several years	Unfertilised	7.8

Different grasses have different leaf:stem ratios (Lodge and Whalley 1983; Robinson and Archer 1988) and, at least for some species, those with the lower ratios have slower growth rates than more valuable, leafy species (Gardener 1998). There is increasing evidence that grazing at high stock densities for short periods of time followed by long periods of rest in appropriate seasons will swing the competitive balance in the direction of the more leafy, faster-growing species and so produce a change in species composition (Earl and Jones 1996; Whalley *et al.* 1999). Grazing animals, therefore, are a powerful tool for the manager to use to either retain or alter the species composition of a grassland, depending on the specific goals of the enterprise.

Conclusions

I have contrasted the ideas in vogue in the 1960s with the more recent recognition that both the manager and the livestock are part of a complex ecosystem. The view of a pasture as a crop to be selected, sown, grown and harvested by grazing animals is extremely limiting and has had unfortunate consequences for much of rural Australia. The goals and perceptions of the manager and the activities of the livestock affect the functioning of the ecosystem in important ways. These effects on the different parts of the system must be clearly recognised if it is to continue to produce animal products and result in economic gain for the manager. This recognition is now becoming widespread throughout the agricultural communities in Australia and is inherent in the teaching of the proponents of Grazing for Profit, Farming for the Future, Holistic Management and Prograze. It is also implicit in many of the results coming out of large programs such as the Sustainable Grazing Systems Key Programme funded by the MLA in southern Australia. I am sure there are others. These different groups have their own emphases but the unifying theme is that managing a property is managing a complex ecosystem in a complex economic environment and that all parts of this functioning ecosystem must be managed and monitored. It is a tall order.

References

CHILCOTT, C. (1998) *The ecological effect of trees in native temperate pastures — nutrient cycling, microarthropods and botanical composition of pastures.* Ph.D. Thesis. The University of New England.

EARL, J. (1998) *The role of grazing management in the functioning of grassland ecosystems.* Ph.D. Thesis. The University of New England.

EARL, J.M. and JONES, C.E. (1996) The need for a new approach to grazing management. *The Rangeland Journal,* **18**, 327–350.

GARDENER, M.R. (1998) *The biology of* Nassella neesiana *(Trin. and Rupr.) Barkworth (Chilean needle grass) in pastures on the Northern Tablelands of New South Wales: weed or pasture?* Ph.D. Thesis. The University of New England.

GREENWOOD, K.L., MACLEOD, D.A. and HUTCHINSON, K.J. (1997) Long-term stocking rate effects on soil physical properties. *Australian Journal of Experimental Agriculture,* **37**, 413–419.

HARRADINE, A.R. and WHALLEY, R.D.B. (1981) A comparison of root growth, root morphology and root response to defoliation of *Aristida ramosa* R.Br., and *Danthonia linkii* Kunth. *Australian Journal of Agricultural Research,* **32**, 565–574.

HARRINGTON, G.N., WILSON, A.D. and YOUNG, M.D. (1984) *Management of Australia's Rangelands.* (CSIRO: Melbourne).

HUMPHRIES, S.E., GROVES, R.H. and MITCHELL, D.S. (1991) Plant invasions: the incidence of environmental weeds in Australia. *Kowari,* **2**, 1–188.

HUTCHINSON, K.J., KING, K.L. and WILKINSON, D.R. (1995) Effects of rainfall, moisture stress, and stocking rate on the persistence of white clover over 30 years. *Australian Journal of Experimental Agriculture,* **35**, 1039–1047.

JONES, C.E. (1995) Value, management and permanence of native grasses. *Fifth Annual Conference, Tasmanian Branch of the Grassland Society of Victoria, July 1995, Launceston, Tasmania.* pp. 42–48.

JONES, C.E. (2000) Grazing management for healthy soils. In: Waters, C.M. (ed.) *Proceedings of the 1st STIPA Native Grasses Association Conference, Mudgee, NSW.* pp. 68–75.

LAZENBY, A. (1967) The agronomist and pasture production. Inaugural Address, Armidale, The University of New England.

LODGE, G.M. (1979) Effect of fertility level on the yield of some native perennial grasses on the North-West Slopes, New South Wales. *Australian Rangeland Journal,* **1**, 327–333.

LODGE, G.M. and WHALLEY, R.D.B. (1983) Seasonal variations in the herbage mass, crude protein and *in-vitro* digestibility of native perennial grasses on the north-western slopes of NSW. *Australian Rangeland Journal,* **5**, 20–27.

LODGE, G.M. and WHALLEY, R.D.B. (1985) The manipulation of species composition of natural pastures by grazing management on the Northern Slopes of NSW. *Australian Rangeland Journal,* **7**, 6–16.

LONSDALE, W.M. (1994) Inviting trouble: introduced pasture species in Northern Australia. *Australian Journal of Ecology,* **19**, 345–354.

MCCLYMONT, G.L. (1969) Nutritional value of plant matter and factors affecting its intake by animals. In: James, B.J.F. (ed.) *Intensive utilisation of pastures.* pp. 38–41. (Halstead Press: Sydney).

ROBINSON, G.G. and ARCHER, K.A. (1988) Agronomic potential of native grass species on the Northern Tablelands of New South Wales. I. Growth and herbage production. *Australian Journal of Agricultural Research,* **39**, 415–423.

WHALLEY, R.D.B., GARDENER, M.R. and EARL, J.E. (1999) Pasture management of reproductively efficient grassy weeds. *12th Australian Weeds Conference, Hobart, Tasmania, Tasmanian Weed Society.* pp. 174–175.