DE-INTENSIFICATION OF GRASSLANDS: UNDERSTANDING THE PROCESSES TO FIND THE BALANCE

K. C. Hodgkinson
CSIRO Sustainable Ecosystems, GPO Box 284, Canberra, ACT 2601, Australia

Abstract

There is a growing trend in Australia and other developed countries for de-intensification of animal production from grasslands and for grasslands to be used for purposes other than livestock grazing. These shifts are occurring for a variety of reasons including unsustainable land management practices, environmental pollution, loss of conservation value, poor commodity prices and declining rural infra-structure and communities. In Australia, the shifts are under way in agricultural grasslands, where sown pastures occur in a matrix of semi-natural woodlands, but less so in the other three major natural grasslands that forms the arid and semi-arid rangelands.

The conversion of natural wooded grasslands to agricultural grasslands, often involving crop/pasture rotations, began over 100 years ago in those regions of Australia where rainfall was sufficiently high and regular to allow cropping and pasture sowing. Later, agricultural research identified soil nutrient deficiencies, found European and African grasses and legumes to utilise the raised fertility and developed machines that raised the scale and efficiency of livestock production. Governments promoted pasture improvement, and with livestock breeding, fibre and meat production per hectare was significantly raised. The Australian people in general, accepted as worthwhile and successful the conversion to agricultural grasslands. Conquering the "bush", taming nature and establishing livestock grazing businesses were seen to be appropriate activities for rural pioneers and later generations.

However, doubts about the long-term sustainability of livestock grazing businesses on agricultural grasslands and to a lesser extent other natural grasslands, have grown in the minds of scientists and pastoralists and now the public. Salt has risen to the surface in many regions from tree removal changing hydrological processes. Soils have poor structure and low potential productivity. Added nutrients and chemicals are moving off property with undesirable and public consequences eg toxic algal blooms in rivers. Significant species extinction within Australia's unique plants and animals are linked to land clearing and pastoral management; survival of many threatened species is problematic. Persistent low commodity prices for traditional products are making many livestock grazing businesses untenable. Rural communities are struggling to survive with the withdrawal of services by Government and major businesses.

These problems are being addressed across many fronts. Foremost there is a substantial and growing ownership of the problems by rural communities through "Landcare" and catchment management groups. Research into the sustainability of low-input native pasture systems, the spatial requirements for remnant and plantation vegetation (amount, location and continuity) to lower water tables, ecosystem services and processes involving native plants and animals, effective mechanisms for knowledge sharing and alternative land uses are underway.

Introduction

A trichotomy in the intensity of pastoral businesses is particularly evident in Australia today. Intense livestock production systems rely on high inputs of human, nutrient and/or water and structural resources, coupled with precision management of the added resources. Low intensity systems occur where rainfall is too low and unreliable for the reliable establishment of sown pastures as in grazed rangelands (Stafford Smith 1996), land is too steep for cultivation or because pastoralists have chosen to operate a low intensity system. In the middle are the majority of pastoral businesses, many of which are failing to capture the benefits of intense systems, and are de-intensifying their production for various reasons. The de-intensification is of two forms; the reversion of cultured and sown grasslands to native wooded grasslands for a low input livestock production system or land use change out of livestock grazing.

Most pastoral businesses are seeking greater profit; "intensifiers" are striving to raise the livestock output per unit of land and other inputs and "de-intensifiers" are striving to lower costs of management inputs and gain efficiencies. Land use change to non-pastoral uses is also occurring in both the agricultural and semi-natural grasslands (rangelands), as rural people strive to achieve profitable businesses.

In addition to profit seeking, managers of Australian pastoral businesses based on grassland increasingly are required to address environmental and ecological problems. These problems may affect the resource base of their enterprise, such as soil salinity, or are shared concerns of the wider community, such as loss of biodiversity. Pastoral managers are increasingly being challenged, in simple terms, to find a new balance between production and conservation goals.

De-intensification of grassland production systems is occurring elsewhere in the world. Reasons for the change differ according to the cultural, economic and political situation in each region and country, including the commitment to trade liberalisation and abandoning agricultural subsidies. The extent to which Australia mirrors the international trend is problematic. Australia is a large country with an array of temperate to tropical and arid to humid environments, large natural grasslands and a political scene where the Federal Government maintains a policy of minimal direct subsidy to rural and other industries. In 1999 the OECD percentage Producer Support Estimate was 6% for Australia - only New Zealand was lower at 2% - and the European Union was 49% (OECD, 2000). This "equal playing field" policy of Governments, is strongly driving de-intensification in Australia through removal of any form of income support and as such, sets this country apart from most others.

In this paper, (1) the nature of de-intensification in the four major grassland types in Australia is briefly described, (2) the drivers of the process are identified, and (3) some future directions are proposed for policy, pastoral communities, institutional arrangements and research needed to meet societal and pastoral needs for profitable and sustainable livestock production in Australia.

Nature of Australia's grassland industries

Australia has four major grassland types (Figure 1); three are in a semi-natural state (hummock, Mitchell and semi-arid wooded grasslands) and the fourth, agricultural grasslands are a matrix of periodically cultivated land amongst remnant woodland vegetation of various sizes and connectivity.

The nature of the grassland industries based on these is strongly shaped by the nature of the soils, grassland vegetation and associated biota and the climate. The resource base and environment control the limits and characteristics of the pastoral and other linked grassland industries, such as nature conservation and tourism. In addition, the grassland landscape shapes the attitudes of the people that live there or visit and the important interaction between them (Fitzhardinge, 1999). The pastoral people comprise some of the indigenous Aboriginals but most are the descendants of Europeans who migrated to Australia during the past 215 years. People come to these grasslands also as miners, tourists and a range of other occupations; their aspirations are many and complex.

Australian soils are very old, severely leached and infertile. This is primarily a consequence of the geological inactivity of the continent over recent millennia. Australia is the only continent with entirely passive continental margins. There has been no mountain building in Australia since New Zealand and New Caledonia separated from its east coast 90 million years ago (Flannery, 1994). Erosion of the low range of eastern mountains has provided little fluvial soil. The western two-thirds of Australia has been geologically comatose for hundreds of millions of years. Erosion and leaching have characterised the continent's soils over this long time and low fertility soils are dominant except in local small deposition zones. Soil infertility has a large impact on the way pastoral people conduct their businesses.

Australia is also the smallest, driest and most isolated of the continents. Significantly, the rainfall is the most variable of any continent in the world (McMahon *et al*. 1992). Its grassland flora and fauna have evolved in a different direction from that of the rest of the planet. This isolation in evolutionary time has led to a unique flora and fauna that are the pride of most Australian people, even though their knowledge of even the larger sized components of the biodiversity is limited. This unique Australian biota is part of, and dependent on, the grassland ecosystems that exist in Australia. These grassland ecosystems evolved from about 20 million years ago when the vegetation covering the Australian continent was tropical rainforest.

One striking aspect of the Australian large-sized herbivore fauna is that the combined grazing pressure of these herbivore populations has been light and itinerant until very recently. The marsupial fauna of 20 to 5 million years ago lacked any grazing species – they were all arboreal browsers with the exception of a wombat. About 5 million years ago, members of the present day genus *Macropus* (the larger kangaroos) and a variety of wombats appear in the fossil record. Kangaroos do not form large permanent groups, like bison herds, and their numbers were kept low by the scarcity of permanent water especially in the inland. The natural grasslands of Australia were only lightly grazed but this changed drastically with the recent (post-Aboriginal) wave of colonisation. These colonists brought domestic livestock and established artificial water points needed to support them in an otherwise largely dry continent.

Aboriginal people arrived in Australia about 60,000 years ago (Flood, 1999) and there is equivocal evidence that they substantially altered the flora and fauna by their extensive use of fire and hunting (Flannery, 1994). The second influx of people commenced with the arrival of the First Fleet that set out from England in 1787 to establish a convict settlement in the eastern State of New South Wales. These European settlers and later waves of people from many parts of the planet brought a

range of domestic plants and herbivores from England, Europe and Africa, some of which became feral pests, for example rabbits, pigs and goats.

Temperatures over the continent are suitable for plant growth and reproduction; there are only limited locations where extreme temperatures severely limit plant growth in some seasons. Rainfall, however, in much of southern and central Australia is low and erratic; droughts, fire and floods therefore tend to occur in cycles determined primarily by the Southern Oscillation. In the north the climate is tropical and there is a regular "wet" season accompanying the summer monsoon. The Southern Oscillation magnifies the difficulty of all aspects of land management. The European-based agriculture and intensive livestock husbandry systems in Australia are perilous ventures; the financial and economic systems that were developed in highly seasonal Northern Hemisphere environments, place undue 'seasonal' demands on primary producers striving to cope with considerable annual variation in grass and livestock production.

In summary it can be said that the Australian grasslands evolved under conditions of erratic droughts, low soil fertility and low grazing pressure. These grasslands are complex ecological systems with many interwoven levels of interdependence between organisms that have evolved over many millions of years of isolated co-evolution. Adaptation of perennial grasses to survive the combined pressures of drought and grazing is poor and there are many "death traps" for them in these grasslands (Hodgkinson, 1995). The landscapes of the grasslands vary in the way they organise the limiting resources of nutrients and water (Ludwig *et al.* 1997) but all are prone to dysfunction and biological collapse with intensification of grazing pressure.

Hummock Grasslands

The hummock grasslands (2,010,000 km^2) occupy 23% of the continent. They are located in the western part of the arid interior (Figure 1). For Australians, these grasslands epitomise the quintessential desert heartland, described in detail by Griffin (1984).

The hummock grasslands take their name from the physical shape of the grasses that dominate the vegetation. They belong to the endemic genera *Triodia* and *Plectrachne*, and are perennial, highly unpalatable, evergreen grasses that grow as rounded hummocks. Sparse, low trees and shrubs of many species are also a feature. These grasslands comprise a rich and diverse flora (Maconochie, 1982). The mostly sandy soils are both stable and infertile. Fauna is also abundant and diverse, the hummock grasslands supporting the world's richest lizard fauna (Pianka, 1969).

Extremely high temperatures are recorded here and mean annual rainfall is as low as 125 mm. The infrequent but often intense rainfall drives the biological activity such as plant germination and reproduction, and the landscape processes (Ludwig *et al.* 1997).

These grasslands are unimportant for the pastoral industry of Australia. Peripheral areas supporting more nutritious pastures allow a small number of stable pastoral businesses. Mining of iron ore and others minerals in the Pilbara region of western Australia is a major industry as is the local and international tourist industry which contributes significantly to local economies.

Although remote from coastal cities and other towns, the management of this grassland is critical for conserving the natural resources in these ecosysytems. The fire regimes have changed with the loss of the patchwork successional pattern so

important for the maintenance of habitat and food supplies required by the unique array of faunal species. Today, large-scale wildfire started by lightning is the norm because the Aboriginal people, once nomadic but now focused in small scattered settlements, have nearly lost the knowledge and interest to burn these grasslands like their ancestors. They lit many small fires, either under cool conditions or in restricted patches of suitable fuel. The many purposes for which fire was used meant that it was used almost daily to create burnt patches (Kimber, 1983). The build-up of a mosaic in space and time in this way established a patchwork of successional states, which both inhibited the spread of wildfire and provided a highly patchy but dynamic ecosystem for a diverse and abundant flora and fauna. Today, de-intensification of the fire regimes set up by Aboriginal people is occurring in the hummock grasslands with the demise of traditional aboriginal ways. The changed fire regimes will reduce the survival ability of certain species, especially amongst the fauna, bringing about rarity or worse, extinction.

Mitchell Grasslands

The Mitchell grasslands occur in a broken arc across northern Australia from the northwest to a region in the mid-east (Figure 1). These ecosystems occupy 320,000 km^2. Their nature and pastoral use are described in detail elsewhere (Orr and Holmes, 1984).

These grasslands occur within a region where summer rainfall is dominant and the average annual rainfall is between 250 and 550 mm. Within this envelope the Mitchell grasslands are restricted to cracking clay soils with a uniform profile. Soil fertility is generally high and plant growth is not usually limited by nutrient supply. The dominant grasses belong to the genus *Astrebla* and there is a diverse annual flora. Native trees and shrubs are rare.

Extensive grazing by sheep and cattle commenced late last century and remain as the predominant use of the Mitchell grasslands. There is wide variation in quality of forage for livestock because of the influence of rainfall variation on recruitment and growth of annual forbs – this affects the reproduction of sheep and the ability of businesses to fatten livestock at critical times. De-intensification is only occurring when large tracts of land are set aside for biodiversity conservation.

Although generally stable under grazing, these grasslands are being invaded by introduced exotic shrubs, especially *Acacia nilotica.* They reduce forage production, obstruct livestock management and restrict livestock access to water. However at this stage these "woody weeds" do not appear to be driving any de-intensification of livestock production enterprises in these grasslands.

Semi-arid Wooded Grasslands

The semi-arid wooded grasslands occur in tropical (where they are also called savannas) and temperate Australia in a broken band around the hummock grasslands (Figure 1). There are distinctive vegetation types within this complex but here they are considered as a single complex. As such this is the largest grassland type in Australia occupying nearly 3,000,000 km^2. The component grassland ecosystems are described in detail elsewhere (Harrington *et al.* 1994).

The soils of these grassland ecosystems are generally infertile. However, within the landscapes are many small patches of higher fertility where surface water has carried nutrients to be captured and held to become resource rich 'sinks'. A wide

variety of tussock grasses occur naturally and, because of the high frequency of seasonal or episodic droughts, few exotic grasses have successfully established. Common tree species belong to the genera *Acacia, Casurina* and *Eucalyptus* and there is a large number of shrub species. These lands contain a rich array of flora and fauna, particularly birds.

Domestic livestock have grazed these lands for up to 150 years; cattle in the north and sheep in the south. They are the classic "outback" lands of extensive pastoral businesses. However, mining is an important industry in many parts of these lands as is tourism. Increasingly, pastoralists are operating a tourist enterprise in conjunction with their pastoral business. There has also been a small but steady change of land use from pastoralism to National Parks and other forms of reservation for nature conservation.

De-intensification of pastoral businesses is occurring throughout these lands although the pattern in space and the nature of the drivers, are not consistent. Conservation of natural resources is an important driver and areas of wooded grasslands are being set aside from grazing where there is inadequate representation of particular ecosystem types in the national network for biological reservation. Lower livestock density, along with better management of total grazing pressure, is increasingly practiced to limit loss of perennial grasses and of landscape function through overgrazing at times of drought (Ludwig *et al.* 1997). Land claims by Aboriginal people with non-European aspirations are changing land use to less intense pastoral systems or some other use. Increase in native shrubs and trees (called "woody weeds") in the absence of fire is also reducing the number of livestock in many parts of these lands.

Agricultural Grasslands

The agricultural grasslands are located in the southwestern corner and the southeast of Australia (Figure 1). Here there is relatively reliable winter rainfall. However, the probability of droughts at any time of the year, but especially during summer and autumn, is reasonably significant and can strongly impact on the productivity and financial viability of the pastoral businesses. The higher rainfall and more fertile soils have led to the development of intense livestock production systems. These intense systems occur in valleys and as such the landscape is fragmented with a patchy distribution of remnant vegetation on hills.

Many more people live and work here than in the other grasslands but most Australians still live in a few coastal cities.

Pastoral industries were well established in these wooded grassland ecosystems by the end of the 19th century and they were almost completely based on native herbaceous flora. Trees and other native vegetation were cleared setting up a practice that continues, although much reduced, to this day. The dominant native grasses at the time of settlement were warm-season species that were frost susceptible and quickly lost nutritive value in the winter. Various attempts were made to introduce cool-season European grasses and legumes that would continue growing in winter, but these were only successful on the most fertile sites in higher rainfall areas.

Modern agriculture began in the agricultural grassland ecosystems at the turn of the last Century. State Departments of Agriculture established experimental farms and investigated crop/pasture rotations, the use of superphosphate and the establishment of clovers and European grasses. New forage plants were systematically introduced from around the world. By the early 1930's these practices

were well established but were not very successful on certain soil types and in certain districts. Pasture improvement was limited to arable land.

From 1930's to 1960's pioneering research on the importance of trace elements in pasture and livestock nutrition was conducted and there was rapid uptake of the solutions. After the end of the Second World War there was rapid expansion of "improved" pastures with the development of aerial agriculture pioneered in Australia and New Zealand. In the 1950's there was a concerted effort to increase the stocking rate on "improved" pastures in order to utilise the additional forage and to maximise the return on investment. Native pasture species were completely discounted on the grounds of being incapable of high production in response to high levels of fertility. The prevailing view was that native grasses were only adapted to poor soils, light grazing by nomadic soft-footed marsupials and possibly also to drier climatic conditions than the present (Donald, 1970).

A severe drought in 1965 and the widespread death of many trees in pastures shifted thinking by pastoralists and the observant public increasingly concerned about environmental and conservation problems, to the need for a land management where long-term sustainability of natural resources rather than short-term production, was the goal. The environmental problems that had emerged were the rise of soil salinity in local areas, widespread soil acidification from agricultural practices and loss of biodiversity, especially amongst the charismatic birds and marsupials. Research began in the 1970's to gain better understanding of the processes that determine botanical composition of semi-natural pastures and in particular the effect of time and intensity of grazing, and time and length of rest (Lodge and Whalley, 1985). However, research on the more fundamental problems of resource degradation lagged because of the strong prevailing focus on high intensity production.

The Australian people in general, accepted as worthwhile and successful the conversion to agricultural grasslands. Conquering the "bush", taming nature and establishing livestock grazing businesses were seen to be appropriate activities for rural pioneers and later generations. However, increasingly the general public has become concerned about the natural environment and the impact of livestock production and pasture improvement on the environment and nature conservation. Governments have established new legislation dealing with conservation of native vegetation and many pastoralists see this as political encroachment on the rights of landowners to manage the land as they see fit. Currently in these agricultural grasslands, the majority of pastoralists are caught in a financial and management trap; they do not have sufficient profit, and sometimes knowledge, to raise the intensity of production nor are they convinced they should de-intensify and embrace emerging technologies for low input systems.

Drivers of de-intensification

There is no single aspect of livestock production from grasslands that is driving de-intensification. Rather there are complexes of economic, social and ecological factors that vary spatially in their relative importance. Some drivers originate at the general public level while others arise from changed circumstances at the property level. The major factors driving the change are discussed below.

Narrowing price:cost ratios

Livestock products from grasslands are consumed or processed in countries of origin with the excess traded on the world market. Australia as a traditional exporting country has suffered from the persistent low prices for exported produce during the last decade due to excesses in production over demand, especially in Europe and the USA.

The average financial performance of pastoral businesses has steadily declined over recent decades and continues to do so (Martin, 1999). Overall, about 30 per cent of the pastoral businesses in Australia had a negative farm cash income in the 1998-99 financial year. Declining incomes arise from increasing costs of production and low prices for many commodities, especially meat and wool. Differences exist in the average losses per enterprise (Table 1) but significant proportions (22-35%) of all livestock businesses are currently uneconomical (ABARE, 1999). As a consequence, business debt and infrastructure replacement costs are rising across rural Australia. Wheat and other crops are modestly profitable on average and more arable land is now being cropped.

Although the average picture is dismal, there are wool producing pastoralists who are highly profitable when they adopt proven research results (Lean *et al.* 1997). They are able to achieve profitable and sustainable systems by increasing gross income rather than by reducing costs.

The low prices for meat and fibre on international markets are likely to continue, because of a world excess of production over demand. Australia as a major exporting country has no choice but to produce more efficiently and seek niche markets for some products. This will be easier in the agricultural grasslands where options for product type and quality are much greater than the arid and semi-arid rangelands. However, even in the rangelands there is scope to supply young domestic livestock for fattening in agricultural grasslands or as recently developed, to supply live sheep and beef animals to specific niche markets in the Middle East and Indonesia. An optimistic view for Australian rangelands is that they might provide a marginal surplus in livestock products to trade for other food groups and essentials for lifestyle (Howden *et al.* 2001).

Narrowing price:cost ratios are affecting the profitability of pastoral businesses in all regions and, in general terms, the “rangeland” grasslands (Mitchell and semi-arid wooded) are as severely affected as the agricultural grasslands. However, the scope for alternative land uses and intensification is much lower in the rangelands. In response to a narrow price:cost ratio, pastoralists are seeking either to intensify the level of management and inputs or to seek yet further reductions in costs of production. Typically, many who speak at forums about the problem perceive that they can not further reduce costs nor change their style of management (Nicolson, 2000).

Rising water tables and salinity

Rising groundwater and the salt carried in it, is a growing problem in the agricultural grassland ecosystems (Creighton *et al.* 2000). More than 2.5 million hectares of agricultural land are now affected; water quality, agricultural production, infrastructure and biodiversity are all impacted. The current loss to agricultural production is about $130 million a year with a loss in capital value of about $700 million. These costs to agriculture are masked by productivity gains.

A recent audit (Murray-Darling Basin Commission, 1999) of the salinity problem in the largest and most productive area in the agricultural grasslands, the

Murray-Darling Basin in southeast Australia revealed alarming trends. At least a fourfold increase in the affected land is predicted over the next three to four decades, with estimates suggesting up to 15 million hectares will potentially be affected. Stream salinity increases will be marked with the water at the mouth of the Murray River exceeding the 800 EC threshold for acceptable drinking water quality in the next 50-100 years.

Dry land salinity results from hydrological imbalance within catchments such that the geological salt stores are brought to the surface. It is now understood that the amount of water added to the catchment surface through rainfall, and the timing and amount of the rain, are critical determinants. Land use determines soil water status particularly through evapo-transpiration and hence the amount of water available in the root zone that can infiltrate to the ground water system. The amount of salt stored in the catchment and its spatial distribution determines the mobilisation of salt by ground water. The structural and geomorphic features of the catchment determine how much ground water can be stored, how far it will flow, and what will cause the water to discharge.

The salt has been blown in from the sea over millions of years and because Australia is a dry continent, the salt has not been flushed out. The salt-bearing soils are extensive. Until recently the precise locations and characteristics of salt stores in the landscape could not be mapped. Recent progress with airborne electromagnetic detection systems (Dent and Braaten 2000) that can locate salt to a depth of 150m below the surface will soon redress this problem and open the way for setting water and salt delivery targets at property, catchment and regional scales. Pastoralists and Governments will soon be able to contemplate a market in salinity and infiltration credits and be able to target remedial management.

However the current consensus is that dry land salinity control will not be achieved quickly in many parts of agricultural grasslands. Although an understanding of salt store location and ground water flow systems is imminent , the social and economic opportunities for changed land use, and the long-term commitment of the community at all levels to develop a consistent framework for assessment, planning implementation and monitoring, is some way off.

Salinity and management for local, intermediate and regional ground water flow systems, require varying levels of government involvement including a range of policies, differing emphasis on land use changes, a number of incentives and regulations and monitoring activities.

It is now conceded that the best of current management practices in agricultural grasslands systems cannot reduce current leakage rates to anything approaching those under native vegetation. There is a need for substantial de-intensification of grassland use in the higher rainfall parts of the Basin and widespread planting of forest patches to significantly reduce leakage. The widespread return to native vegetation in most parts of the Basin would be highly desirable but is unlikely without large ongoing incentives from governments. Increased use of proven farming systems, utilising deep-rooted perennial forages such as lucerne (*Medicago sativa*) and phalaris (*Phalaris aquatica*) in combination with strategic planting of forest patches would substantially ameliorate the problem.

The long term challenge is to develop institutional arrangements, planning and evaluation approaches, and policy development and implementation programs that support and foster community activity and recognise both the varied and long term nature of the salinity control problem. If this cannot be achieved then substantial de-intensification of the agricultural grasslands will occur.

Nutrient and chemical leakage from farms

The application of fertiliser, especially phosphates, is generally suspected as the main source of rising nutrient levels measured in streams and rivers draining catchments where intense agriculture is a widespread practice. Naturally acid soils and those with increased acidity from pastoral management have a low ability to "hold" certain nutrients. Chemicals used in weed and animal pest management continue to be of concern to public health and biodivesity when they enter the food chain.

Studies are now being conducted to quantify the leakage of nutrients from intensely managed cultured pastures and to develop solutions. For example, a field study in the high rainfall zone of the southeastern agricultural grassland ecosystems showed that losses of nutrients and water were substantial from existing pastures. However, by replacing the annual pastures with perennial grass and legume pastures, and applying lime on the strongly acid soils, there were substantial benefits in terms of livestock production, improved soil quality, enhanced water use and hence less surface run-off and deep drainage (White *et al.* 2000).

Although scientists have been aware of the problem for over two decades, research to monitor the problem and find solutions has been inadequate and poorly focussed. Reduction in the application of fertiliser to agricultural grasslands, due to narrow price:cost ratios, has delayed development of environmental problems but nutrient leakage remains a "sleeping-giant".

Biodiversity conservation

The general community is becoming increasingly aware, through newspaper articles, school education and TV and radio programs, of the large number of floral and faunal species that have recently become extinct because of livestock grazing, and that many surviving species are threatened (Leigh and Briggs, 1992).

Governments at all levels are adopting the view that Australia has, and still is, under-investing in management of biodiversity, and that the whole community needs to contribute to the solution. Increasingly, biodiversity is recognised as a goal that is just as important as economic development (Young *et al.* 1996).

Australia's flora and fauna, because of the geographical isolation of the continent, is comprised of 80 per cent endemic species. To date it has been recognised that there are 83 plant species presumed to be extinct in Australia. Most of these have been lost from agricultural grassland ecosystems. Of greater concern is a further 840 species that are categorised as threatened, that is, either endangered or vulnerable in grazed landscapes. These species are in danger of extinction in the next 10 to 50 years unless appropriate remedial action is taken.

It is now understood that the formal reserve system of National Parks and other conservation reserves are very important for nature conservation but are inadequate on their own to meet biodiversity conservation goals; improved "off-reserve" conservation is essential to arrest biodiversity loss. Only 48.8% of the threatened species have at least some of their population within National Parks or proclaimed reserves set aside from the grazing of domestic livestock. Of this reserved total, only 13.7% are categorised as 'adequately reserved', that is, there are more than 1,000 reproductively mature individual plants known to exist within reserved areas.

The strength of the biodiversity driver is growing, as knowledge improves about the impact of grazing on biodiversity. For example, it was recently reported (Landsberg *et al.* 1999) that in rangeland landscapes there are large changes in the abundance of plant and animal species along the grazing gradients out from permanent water points. Between 19% and 46% of species in 6 major taxonomic groups of fauna and flora decreased in abundance close to water to become locally extinct where water points were close together.

With this emerging knowledge about the impact of grazing on biodiversity in the least disturbed of the grasslands, it is apparent that the vegetation removal from and the grazing of, agricultural grassland ecosystems have been major drivers of the diminished biodiversity. There is now a growing awareness of the need to evaluate all grassland regions in terms of the trade-off's between the relative importance to Australia of livestock production versus conservation status (Morton *et al.* 1995; Stafford Smith *et al.* 2000). Pastoralists typically consider they can satisfy the needs of their family, bank manager and land productivity most of the time but the most difficult is to address the imbalance between the pastoral business and the land's other natural values (Nicolson 2000).

"Clean & green" certification and organic produce

To meet the demands of increasingly critical customers within Australia and beyond, there is a growing requirement for quality control for the livestock products and for the production landscapes. Increasingly, individuals and communities of pastoral people are seeking certification for their products and landscapes. They are required to meet a number of criteria that include pollution-free production, maintenance of biodiversity and efficient energy use. There is no auditing of the energy requirements for livestock production from grassland systems. In general terms (Heitschmidt, 1994), rangeland grazing is the most efficient system producing about 42 energy units of output for every unit of energy input. For different types of developed agricultural grassland the ratio range from 10 to 12.

Consumers pay a premium at the moment for the least efficiently produced and most environmentally damaging products. This may be reversed in the near future as those seeking a "clean and green" certification press their case to gain market share. Whether customers will pay more for "certified" products is problematic but with smart marketing, it seems likely that customers will increasingly choose the "certified" products in a world where environmental and ecological concerns grow to dominate national and international affairs. The success of the organic food system indicates that a significant section of well-informed people would switch to purchase "clean and green" type produce.

In addition to "certification" or other forms of "eco-labelling", the branding of produce on a regional basis, so called "regional branding", may give a group of pastoralists or a processing company a market edge over competitors. This could be assisted by the biophysical, economic, social and biodiversity indicators now being developed and applied to regions of Australian grasslands in the National Land and Water Resources Audit (website: www.nlwra.gov.au).

The way conservation and environmental matters are managed throughout Australia will affect the value of the 'clean and green' certification for products from an individual or group of pastoral businesses. Although the leverage from Aboriginal people managing the large arid hummock grasslands with fire in traditional ways may be small, it is reasonable to assume this would be effective, along with other images,

in marketing Australia as a country that cares for its natural environment and its people.

Whilst it is possible to produce pastoral products from intensive grassland systems that meet "clean and green" certification standards it would be easier to do so from the rangelands where livestock graze semi-native grasslands. In the future, pastoral production from low intensity grassland systems is likely to attract a price premium and drive more pastoral businesses to de-intensify production.

Excessive grazing pressures

Across the grazed grasslands of Australia there are individual pastoral properties where grazing pressures have been excessive at some time(s) resulting in a reduced potential forage productivity of the grassland and associated signs of landscape dysfunction such as soil erosion, weed ingress and perennial grass loss. The semi-arid wooded grasslands have probably lost more of their productive potential through excessive grazing than any other grassland (Stafford Smith *et al.* 2000). Although there is now an adequate understanding of the processes involved and remedial managements required (Hodgkinson, 1992), restoration is problematic where critical ecological thresholds (Westoby *et al.* 1989) have been incessantly crossed.

A survey of pastoralists in the agricultural grasslands (Reeve *et al.* 2000) revealed that there is widespread concern about grassland pasture decline due to inappropriate grazing regimes. Weeds and weed control appear to play an important role in producers' perceptions of the problem and appropriate remedial actions. Producers do not doubt that grazing management might be used to maintain a desirable species composition, but substantial numbers believe that other influences, such as drought, may over-ride the capacity of grazing management to maintain a desirable species composition. There is inadequate knowledge for managing the grazing regimes of agricultural grasslands to achieve desired botanical compositions (Garden *et al.* 2000).

New directions

There are no simple prescriptions for pastoralists and Governments to successfully address the emerging or existing issues that drive the intensification and de-intensification occurring in pastoral Australia. Rather, strategies need to be developed by communities, industries and governments, working together with scientists, and taking into account the issues at all scales (paddock to region), opportunities for land use change and local and national community aspirations.

Policy

There exists at Federal and State levels of government a wide range of policies for land, water and vegetation management. The operation of these however largely occurs at the local government level and this level of government is closest to the pastoral community. Whilst strategic policies are developed by the higher levels of government, it is local government that must make detailed decisions that balance pastoral and other industry development with the need to protect natural resources.

It is argued that local government is the most significant sphere of government in regulating land use (Binning *et al.* 1999). Most local governments are actively involved in managing natural resources but local government is being neglected by

many decision-makers, not only at State and national scales, but also by regional structures, such as catchment management committees. Local governments also generally lack an information transfer capability to access current information arising from research.

It is appropriate that policies are reviewed from time to time and this is occurring at the moment at Federal and State levels for natural resource management. How this will impact on the intensification/de-intensification of grassland use in the future is uncertain but effectiveness will be improved by pastoral people and their organisations being involved. Importantly, there is close cooperation between some important Non-Government Organisations in developing proposals to government, such as a recent paper on natural resource development prepared by the Australian Conservation Foundation and the National Farmers Federation. **The pastoral community and other stakeholders need to participate in policy development, along with industry and government.**

Pastoral communities

Australia has an extensive network of "landcare" groups. These started after urban taxpayers queried governments about dust storms over Melbourne and other places, and major farmer and conservation groups began lobbying Federal Government. The Australian government spent $360 million in the last decade supporting many of these groups. The Landcare movement was intended to achieve more sustainable use of Australia's farming lands and enhance biodiversity (Farley and Toyne, 1989). It has become a catalytic program for engaging pastoral communities and others, and producing more aware, informed, skilled and adaptive resource managers with a stronger stewardship ethic. Roberts (1995) defined a stewardship or land ethic as 'a set of values, which engenders an appreciation of, and respect for, the land as the basis of our prosperity and quality of life'.

Landcare is increasingly heralded as an Australian success story, with more and more developed nations examining Landcare as a model for rural development. Landcare has mobilised a large section of the rural population; embraced a range of community development activities that have increased awareness of issues and enhanced landholder skills and knowledge; and has accomplished on-ground work likely to have an impact upon land and water degradation at the local scale. There are now over 2,500 Landcare groups with 65,000 volunteer members involving about 30% of the pastoral community. Landcare is therefore an important international example of government-sponsored community participation in a developed nation.

However, Landcare has been criticised as an exercise in shifting responsibility for action from the government to local communities. Governments exert considerable control over groups through the allocation of funds to projects that address the government priorities. Staff of agencies play an important role in the decision-making of many groups and group work is significantly related to government funding and information. Others have highlighted important Landcare Group management issues including inadequate leadership and management skills training, inadequate scientific advice and monitoring, low turnover of leadership positions and gender stereotyping with group leadership role. Conservationists are alarmed by continued loss of critical habitats and believe Landcare is not adequately addressing biodiversity conservation.

The two key assumptions underlying the community Landcare program are that attitudinal change leads to behavioural change and groups will accelerate

attitudinal change and development of more appropriate land management systems. A survey of rural property owners in southeast Australia about Landcare (Curtis, 1997) however failed to establish any differences in the stewardship ethic of Landcare and non-Landcare pastoralists. Furthermore, stewardship was not associated with the adoption of best management practices promoted by government agencies. **More emphasis therefore needs to be placed on educating pastoralists about resource issues and systems thinking, thereby raising awareness, rather than by government trying to change attitudes – the capacity of pastoralists to use new knowledge needs to be built.**

Institutional

To support and motivate pastoralists to manage land and water resources and their livestock production business in a sustainable manner may require new institutional arrangements. It has been argued that the underlying causes of environmental degradation and biodiversity loss arise from decisions made by existing bodies. It is therefore probably more efficient to use and adapt existing administrative and institutional structures rather than create new additional structures.

Young *et al.* (1996) proposed for biodiversity conservation that incentives aimed at increasing levels of knowledge and understanding are far more likely to result in responsible behaviour because people will have a basic knowledge of the issues at stake. This means that motivational incentives should be a core mechanism for achieving biodiversity conservation and other management skills that would raise profitability. Voluntary incentives have an important role in circumstances where pastoralists have a genuine interest in protecting the environment and little interest in obtaining financial concession. Regulatory incentives are needed to provide precautionary standards and signals that protect against market failure to value biodiversity and other components of the natural ecosystem.

Research opportunities

The de-intensification of grassland ecosystems and other linked changes occurring in Australia's pastoral industries demand a strong underpinning of innovation. While some changes are driven by global trends, such as sustained slowing meat production (Brown 1999) and persistent low wool prices, the majority of change is coming from the realisation that historical approaches to grassland management in Australia have caused significant environmental problems.

Most changes are not marginal. They involve paradigm shifts that require strategic research with the new parameters and a focus on applied outcomes integrated with improved systems.

The major opportunities for innovation from research would be:

(i) *Enhance the ability of pastoralists to produce high quality products when markets require them.* The shift away from a production-driven approach requires better development of market-driven grass-fed livestock production. Customers are increasingly demanding product consistency, reliability of supply, food safety, and product choice and most recently, sustainability of production. To meet these requirements pastoralists will need to be more flexible in their management and have better business skills. Knowing when to seize opportunities will be as important as knowing when to avoid hazards for product quality.

There is an ethical issue here too underpinning this research. For Australia as a developed country to continue producing grassland products of low to medium quality, neither meets the requirements of increasingly critical home consumers, nor the ethical considerations of denying reasonable markets for produce from developing countries (Foran, 1994).

(ii) *Develop better ecological theory and tools for the management of the natural grassland environment.* The issues of water quality and quantity, soil salinity, acidification and degradation, air quality, climate change and conservation of biodiversity, all require an improved understanding of how semi-natural ecosystems function and how dysfunction can be reversed. Knowledge required to move from a classical agricultural mindset to an ecological approach will involve consideration of spatial and temporal elements, as well as an integration of ecological, economic and social components of what are very complex systems. Research will be required into sustainability of low-input native grassland systems, spatial requirements for remnant and plantation vegetation (amount, location and continuity) to lower water tables and ecosystems services provided by native plants and animals. Outcomes of research will need to be transformed into an array of management tools and aids for pastoral people. Some of these will be readily accepted but for others a demand will need to be built by education on ecosystem thinking.

(iii) *Set up research partnerships between scientists and pastoralists to use knowledge flowing from both scientific inquiry and practical experience.*
To address the emerging issues outlined above will require new frameworks for conducting research. Integrated thinking of social, economic and biophysical issues will require the input of pastoralists. Furthermore, the input of pastoral people will ensure the pastoral community owns and uses the new knowledge.

(iv) *Develop new technologies for high intensity pastoral businesses and the rationale for locating these businesses.* The intensification of appropriately located pastoral businesses will require new knowledge for retaining nutrients on-property and a host of technical innovations to achieve the required efficiencies. New technologies will involve a trend to patented input systems including genetic manipulation of plants and livestock, precision farming and information management using remote sensing and simulation modelling (Simpson *et al*. 2000). The development of an industrialised system of agriculture in some parts of landscapes requires an increased vertical integration, a systems approach to agri-industries and the implementation of industry-wide quality assurance. There will also be a requirement to locate these businesses in parts of landscapes where they can be ecologically sustainable and non-polluting.

(v) *Develop a predictive understanding of the limits to intensification.* While it is generally understood that intensification of grassland has been too widespread and possibly intense in major regions of the agricultural grassland ecostems, there is inadequate understanding of how much simplification of natural grassland systems can occur while maintaining ecosystem function. There are grassland landscapes in the northern part of northeast Australia where there is scope for intensification involving tree clearing but the limits are inadequately understood. The value of native vegetation for providing ecological services to livestock production, cropping and

other agricultural uses of land is not understood but is a key component of the understanding required to determine the limits for intensification.

Finding the balance

In Australia, there is a general call to find the balance between production and conservation and other environmental tensions, often expressed as "sustainable development", for the different grassland ecosystems and regions within each. There are no obvious recipes but the search needs to gather momentum quickly. The search needs to be conducted at all scales relevant to land use planning, including property, catchment, regional and national levels (McIntyre, 2000). The scale at which there is a large knowledge gap is the regional scale. To find the balance new knowledge is urgently required on how regional systems function and how the components (people, finance and natural resources) interact.

Where there is inadequate knowledge about ecological thresholds and system processes for determining the limits to intensification in grassland ecosystems, the precautionary principle should apply throughout Australia with respect to vegetation clearing and intensification. However, it seems reasonable for individual pastoralists to further intensify their livestock production systems if it does not involve clearing of remnant vegetation and where there is local maintenance of ecosystem function values.

This is likely to apply where there is a matrix of "corridors" of semi-natural vegetation that is fully meeting overall requirements for maintaining ecosystem function. Such intensification should provide pastoralists with much needed profitability for managing the patches of remnant vegetation. In other areas de-intensification is urgently required to address salinity and biodiversity conservation goals.

In finding the balance, the full involvement of pastoralists is paramount. The challenge ahead is to find pathways for sharing responsibility between pastoralists, government, industries and the general public. There is no single most appropriate operational scale for addressing the issues; all spatial and institutional scales must be involved.

Acknowledgement

I gratefully acknowledge the support from Margaret Hindley and Rod Edmundson in searching literature during the writing of this paper. The scientific comments of Dr Doug Cocks, CSIRO Sustainable Ecosystems, Dr John Donnelly, CSIRO Plant Industry and Dr David White, ASIT Consulting, greatly improved this paper and I appreciated their insights.

References

ABARE (1999). Australian Farm Surveys Report 1999. Canberra: Australian Bureau of Agricultural and Resource Economics.

Binning, C., Young M. and Cripps E. (1999). Beyond Roads, Rates and Rubbish: Opportunities for local government to conserve native vegetation. National R&D Program on Rehabilitation, Management and Conservation of Remnant Vegetation, Research Report. 1/99. Canberra: Environment Australia. p. 148.

Brown, L.R. (1999). Meat production growth slows. In: Starke L.(ed) Vital Signs 1999 2000 The Environmental Trends that are Shaping our Future. London: Earthscan Publications. pp. 34-35.
Creighton, C., Coram J., Dyson P. and Webb A. (2000). Managing dryland salinity. In: Outlook 2000. Procedings of the National Outlook Conference, 1, pp. 97-103. Canberra: ABARE.
Curtis, A.L. (1997). Landcare, stewardship and biodiversity conservation. In: Klomp N. and Lunt I. (eds) Frontiers in Ecology: Building the Links, pp. 143-154. Oxford: Elsevier Science.
Dent, D.L. and Braaten R.O. (2000). Chasing down the salt. In: White D.H. and Walcott J. (eds) Emerging technologies in Agriculture: From ideas to adoption. Canberra: Bureau of Rural Sciences. (in press and www.brs.gov.au/agrifood/confEtiA7-00/index.htm).
Donald, C.M. (1970). Temperate pasture species. In: Moore R.M. (ed) Australian Grasslands. pp. 303-320. Canberra: Australian National University Press.
Farley, R. and Toyne P. (1989). A national land management program. Australian Journal of Soil and Water Conservation, **11**: 6-9.
Fitzhardinge, G. (1999). People and landscape: growing together or growing apart. In: Eldridge D. and Freudenberger D. (eds) People and Rangelands Building the Future. Proceedings of the Vith International Rangeland Congress. **1**: 56-60.
Flannery, T.F. (1994). The Future eaters. An Ecological History of the Australasian Lands and People. Sydney: Reed Books.
Flood, J. (1999). Archaeology of the Dreamtime: The Story of Prehistoric Australia and its People. Revised Edition. Pymble: Harper Collins.
Foran, B. (1994). A time for change - Issues arising from the XVII International Grassland Congress from a developed world viewpoint. In: Proceedings of the XVII International Grassland Congress, Palmerston North, 1993, pp. 2251-2256.
Garden, D.L., Lodge G.M., Friend D.A., Dowling and Orchard B.A. (2000). Effects of grazing management on botanical composition of native grass-based pastures in temperate south-east Australia. Australian Journal of Experimental Agriculture, **40**: 225-245.
Griffin, G.F. (1984). Hummock grasslands. In: Harrington G.N., Wilson A.D. and Young M.D. (eds) Management of Australia's Rangelands, pp. 271-284. Melbourne: CSIRO.
Harrington, G.N., Wilson A.D. and Young M.D. (1984). Management of Australia's Rangelands. Melbourne: CSIRO.
Heitschmidt, R. (1994). The ecology of grazing management. In: Proceedings of the XVII International Grassland Congress, Palmerston North, 1993. pp. 1267-1270.
Hodgkinson, K.C. (1992). Elements of grazing strategies for perennial grass management in rangelands. In: Chapman G.P. (ed) Desertified Grasslands: Their Biology and Management, pp. 77-94. London: Academic Press.
Hodgkinson, K.C. (1995). A model for perennial grass mortality under grazing. In: West N.E. (ed) Rangelands in a Sustainable Biosphere, Proceedings Vth International Rangeland Congress **1**: Salt Lake. pp. 240-241.
Howden, S.M., Foran B. and Behnke R. (2001). Future shocks to people and rangelands. In: Grice A.C. and Hodgkinson K.C. (eds) Global Rangelands: Progress and Prospects. Oxon: CAB International. (in press).
Kimber, R.G. (1983). Black lightning: Aborigines and fire in central Australia and the western desert. Archeaology in Oceania, **18**: 38-45.

Landsberg, J.J., James C.D., Morton S.R., Hobbs T., Stol J., Drew A. and Tongway H. (1999). The effects of artificial sources of water on rangeland biodiversity. Biodiversity Technical paper. 3. Canberra: Department of Environment and Heritage.

Lean, G.R., Vizard A.L. and Webb Ware J.K. (1997). Changes in productivity and profitability of wool-growing farms that follow recommendations from agricultural and veterinary studies. Australian Veterinary Journal, **75**: 726-731.

Leigh, J.H. and Briggs J.D. (1992). Threatened Australian Plants: Overview and Case Studies. Canberra: Australian National Parks and Wildlife Service.

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 New South Wales. Australian Rangeland Journal, **7**: 6-16.

Ludwig, J.A., Tongway D.J., Freudenberger D.O., Noble J.C. and Hodgkinson K.C. (1997). Landscape ecology, function and management: principles from Australia's rangelands. Melbourne: CSIRO.

Maconochie, J.R. (1982). Regeneration of arid zone plants: a floristic survey. In: Barker W.R. and Greenslade P.J.M. (eds) Evolution of the Flora and Fauna of Arid Australia. pp. 141-144. South Australia: Peacock Publications.

Martin, P. (1999). Financial performance of surveyed industries. Australian Farm Surveys Report, pp. 1-22. Canberra.

McIntyre, S. (2000). Ecological limits to pasture intensification. In: Barlow T. and Thorburn R. (eds) Balancing Conservation and Production in Grassy Landscapes, pp. 162-169. Canberra: Environment Australia.

McMahon, T.A., Findlayson B.L., Haines A.T. and Srikanthan R. (1992). Global runoff – continental comparisons of annual flows and peak discharges. Catena Paperback, 165 p.

Morton, S.R., Stafford Smith D.M., Friedel M.H., Griffin G.F. and Pickup G. (1995) The stewardship of arid Australia: ecology and landscape management. Journal of Environmental Management, **43**: 195-217.

Murray-Darling Basin Commission (1999). The Salinity Audit of the Murray-Darling Basin: a 100-year perspective, 1999. Canberra: Murray-Darling Basin Commission.

Nicolson, L. (2000). Farming with nature (1). In: Barlow T. and Thornburn R. Balancing Conservation in Grassy Landscapes. pp. 8-10. Canberra: Environment Australia.

OECD (2000). Agricultural Policies in OECD Countries: Monitoring and Evaluation 2000. Paris: OECD Publications.

Orr, D.M. and Holmes W.E. (1994). Mitchell Grasslands. In: Harrington G.N., Wilson A.D. and Young M.D. (eds) Management of Australia's Rangelands. pp. 241-254. Melbourne: CSIRO.

Pianka, E.R. (1969). Habitat specificity, speciation, and species density in Australian desert lizards. Ecology, **50**: 498-502.

Plumb T. (1982). Atlas of Australian Resources: Third Series. Volume 3. Agriculture. Canberra: Division of National Mapping.

Reeve, I.J., Kaine G., Lees J.W. and Barclay E. (2000) Producer perceptions of pasture decline and grazing management. Australian Journal of Experimental Agriculture, **40**: 331-341.

Roberts, B. (1995). The Quest for Sustainable Agriculture and Land Use. Sydney: University of New South Wales.

Simpson R., Donnelly J., Graham P., Salmon L., Moore A. and Hill M. (2000). Using technology to improve the sustainability of grazing systems in high rainfall landscapes. In: White D.H. and Walcott J. (eds) Emerging technologies in Agriculture: From ideas to adoption. Canberra: Bureau of Rural Sciences. (in press and www.brs.gov.au/agrifood/confEtiA7-00/index.htm).
Stafford Smith D.M. (1996). Management of rangelands: paradigms at their limits. In: Hodgson, J. and Illius A.W. (eds) The Ecology and Management of Grazing Systems. Owon:CAB International. pp. 325-358.
Stafford Smith, D.M., Morton S.R. and Ash A.J. (2000). Towards sustainable pastoralism in Australia's rangelands. Australian Journal of Environmental Management. (in press).
Weiss, J. and Wills E. (2000). Integrated management of horehound (Marrubium vulgare L.) in Wyperfeld National Park. Plant Protection Quarterly, **15**: 40-42.
Westoby, M., Walker B. and Noy-Meir I. (1989). Opportunistic management for rangelands not at equilibrium. Journal of Range Management, **42**: 266-274.
White, R.E., Helyar K.R., Ridley A.M., Chen D., Heng L.K., Evans J., Fisher R., Hirth J.R., Mele P.M., Morrison G.R., Cresswell H.P., Paydar Z., Dunin F.X., Dove H. and Simpson R.J. (2000). Soil factors affecting the sustainability and productivity of perennial and annual pastures in the high rainfall zone of south-eastern Australia. Australian Journal of Experimental Agriculture, **40**: 267-283.
Young, M.D., Gunningham G., Elix J., Lambert J., Howard B., Grabosky P. and McCrone E (1996). Reimbursing the future: an evaluation of motivational, voluntary, price-based, property-right, and regulatory incentives for the conservation of biodiversity. Biodiversity Series, 9. Canberra: Department of the Environment, Sport and Territories.

Table - 1 Average business profit ($) for pastoral, cropping and dairy enterprises. Source: ABARE (1999).

	1996-97	1997-98	1998-99
Mixed livestock-crops	-786	-1690	-500
Sheep	-16155	-16030	-29900
Beef	-19143	-17730	-4400
Sheep-beef	-12949	-24500	-20400
Wheat and other crops	48641	35930	21200
Dairy	-4542	-4230	-1600

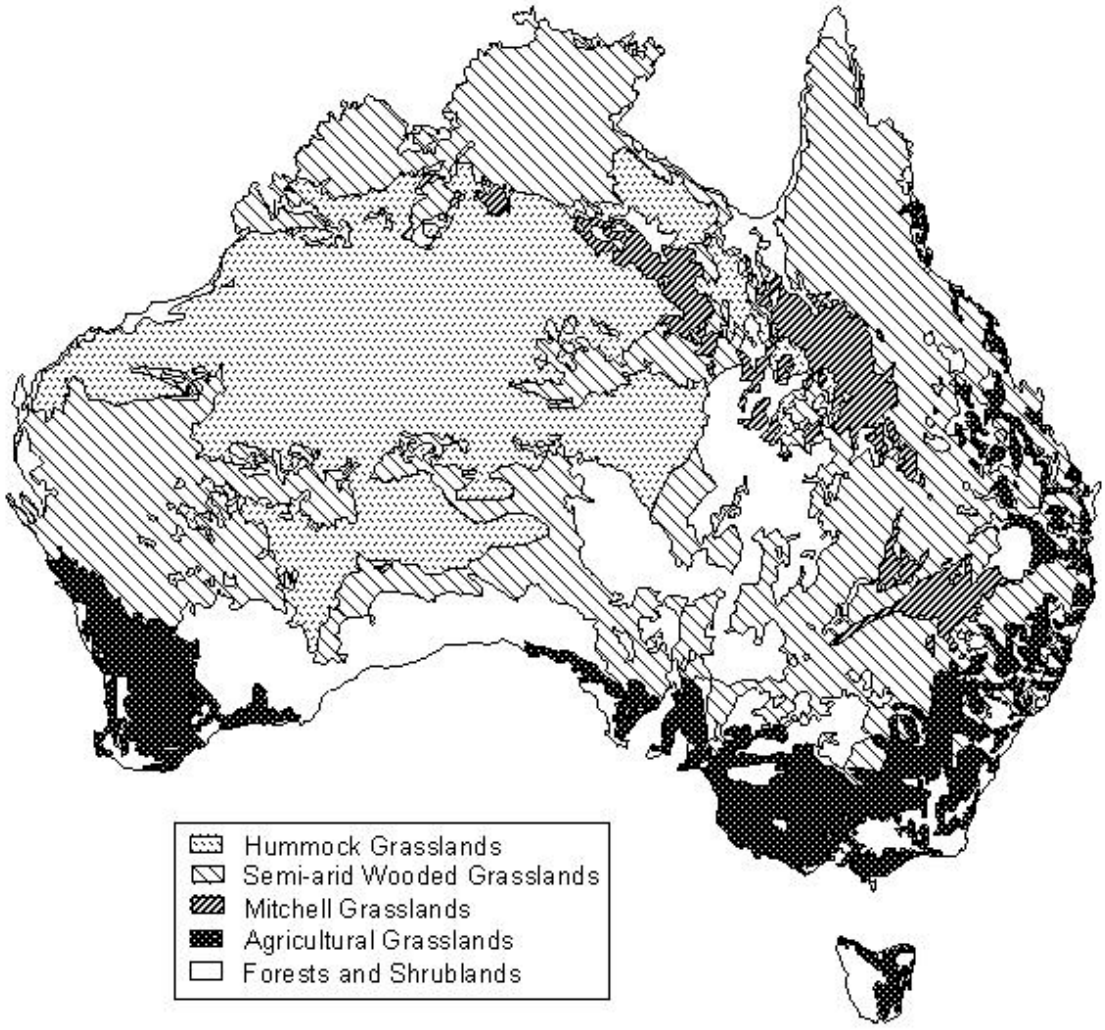

Figure - 1 Distribution of the major grasslands and other vegetation types in Australia. Source: Plumb (1982)