Arid land management

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Abstract

Australia's arid and semiarid lands comprise about 80% of the continent. The human population of around 300,000 is very low. The dominant land use is the pastoral industry. However, other interacting land uses include national parks, mining and aboriginal lands. Some of the impacts of European people on soils, vegetation and native wildlife, following almost 200 years of settlement are discussed.

Management of arid lands for sustainable long-term yield requires integrated studies into the physical and biological environment. The central issue for the administration and management of arid grazing lands is the accurate estimation of grazing capacity in relation to the wide annual fluctuations in available forage for livestock in arid regions. Any estimate for grazing capacity must be such that wool or meat production is maximal, or near-maximal, and that soil and vegetation stability is maintained over the long-term. The basic ecological components for such an arid grazing land management programme are described. The programme also provides the essential information base on which future decisions on land administration issues can be made by policy makers.

Dry areas cover one-third of the earth's land areas and support about one-sixth of the world's population. Mean annual rainfall in these areas varies from less than 60mm to 500mm and it is very unreliable and variable in occurrence. People's use of the world's arid and semiarid lands is resulting in around 70,000 km^2 being degraded each year. In arid areas some of the major causes of land degradation are overgrazing of natural systems, clearing of woodlands and shrublands, improper water management on irrigated lands leading to increased soil salt levels and, in limited areas, open cut mining. Dregne *(op. cit.)* has estimated the percentage of the world's arid lands in relation to their existing degree of degradation (Table 1). Although only a small percentage of land is in a very severe state of degradation, a substantial amount has degraded severely. Around 80% of Australia is under some risk of further degradation through people's use of arid and semiarid lands.

In Australia, although well over three-quarters of the land mass is arid or semiarid, only about 2% of Australia's population lives in this zone. The pastoral industry is the dominant form of land use as rainfall is inadequate for economic crop production or for pasture improvement. There are other forms of land use including national parks, mining and Aboriginal lands; approximately one-third of the zone is unoccupied. There are four basic ecological issues which need to be examined before decisions can be made on the rational use of Australia's arid grazing lands. These are: a) an understanding of the processes of land degradation, b) some integration of the factors controlling plant growth, c) an evaluation of management strategies which maintain a balance between economic animal production and long-term ecosystem stability, and d) an appraisal of the interrelationships between domestic livestock and wildlife. These studies also provide the essential information base on which decisions on land administration issues can be made.

Table I: Percentage of the World's Arid Lands affected by Land Degradation Processes (following Dregne 1979).

Degree of Land Degradation	Percentage of Arid Lands
Slight	18.0
Moderate	53.6
Severe	28.3
Very Severe	0.1

The Major Australian Arid and Semiarid Vegetation Formations

The major vegetation formations are shown in Figure 1. The annual precipitation boundaries in arid and semiarid Australia do not correspond exactly with those on a global basis. In Australia the annual precipitation at the boundaries coincide approximately with the 625mm isohyet across northern Australia, the 500mm isohyet in Queensland, the 375mm isohyet in New South Wales and the 250mm isohyet in southern Australia. However, these mean values do not adequately reflect the very wide annual rainfall variability which limits its effectiveness for plant growth. Based on rainfall effectiveness and the mean annual rainfall, the arid zone of Australia is defined as the area contained within the above rainfall isohyet boundaries; this area receives insufficient rainfall to allow pasture improvement or cropping without irrigation. Depending on location within the zone, there is considerable variation in the seasonal temperature range. In the northern zone summers are very warm (mean temperature of the warmest summer month is greater than 30°C) and winters are mild (mean temperature of the coldest winter month varies from 10 to 20°C). In the southern zone summers are warm (mean temperature range 20 to 30°C) and winters cool (mean temperature range 0 to 10°C). Climatic and soil differences influence the distribution of the major vegetation types. The following description of the four main vegetation types is largely based on Perry (1970).

The mulga *(Acacia aneura)* shrublands are the most widespread of the *Acacia* communities. The shrublands occur on red earths, stony hillsides and on some clayey sands. The growth form varies from tall shrub to a low tree. The tree height and density can also vary with the degree of aridity,

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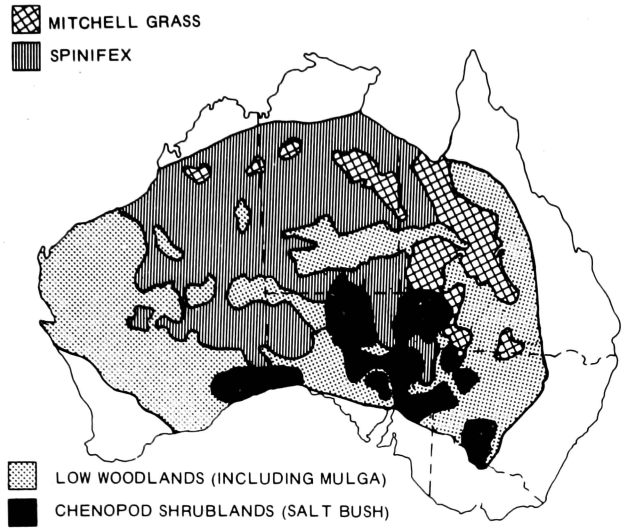
Figure 1: The main vegetation formations found in arid and semiarid Australia (following Moore and Perry 1970).



trees becoming larger and density decreasing as the aridity increases. Mulga is used principally as a drought fodder, as stock mostly feed on the ground-storey of perennial grasses and forbs. To encourage ground-storey production, and hence carrying capacity, the shrublands are thinned out or cleared in strips. The soils are infertile to very infertile which limits seedling growth; seedling survival is reduced so that establishment of perennial plants, if plant cover is lost through overgrazing, is also reduced.

The spinifex communities are arid hummock grasslands and are the most extensive and widespread community in arid Australia; they occupy about one-third of the area. Spinifex communities occur on sites from infertile red sands to rocky hillslopes. The hummock is 1.0 - 1.5m diameter but it may grow up to 20m in some species. Hummocks vary in height from 0.6 - 1.8m, depending on the species of spinifex. The Mitchell grassland *(Astrebla* spp.) communities are dominated by perennial tussock grasses, around 0.5 - 1.0m high, and are found on grey/brown cracking clay soils in the summer rainfall zone of northern Australia. The soils are of moderate fertility. The grasslands occur on flat, mostly treeless plains, with trees generally lining water courses. The perennial grasses are about 1m apart. The spaces between the tussocks are bare in dry seasons but support annual grasses and forbs in response to good seasonal rains. These annual grasses and forbs, when present are grazed in preference to the Mitchell grasses.

Chenopod shrublands are 1m or less in height and occur in the predominantly winter rainfall zone of southern Australia. The shrublands are composed of either saltbush *(Atriplex* spp.) or bluebush *(Maireana* spp.) in monospecific stands, but mixtures of two or more species exist on some sites. Chenopod shrublands occur on a variety of soils, mostly texture contrast with depth, or coarse to medium textured calcareous soils. The terrain is gently undulating. Erosion hazard of these soils is high if the shrubland cover is destroyed by overgrazing.

Each system does have one factor in common and that is the enormous annual variation in net primary production. This is one of the central issues in their grazing management and in land degradation.

Stability of Australia's Arid and Semiarid Grazing Lands

With their shorter history of settlement, Australia's arid and semiarid lands are generally less degraded than similar lands overseas. Many vegetation systems have been degraded severely, although the extent of degradation is unequal. Some systems such as the shrublands (e.g., saltbush; mulga) have deteriorated to a much greater extent since occupation than grasslands, such as the Mitchell grasslands. In western New South Wales alone, about 208,000 km^2 of semiarid and arid lands have been eroded, much of it so severely that it is difficult to restore under present economic conditions. Experience in Australia has shown that, ever after 30-40 years of protection, some badly degraded areas have not recovered (Perry 1966). The impact of European man on arid grazing lands, since settlement, is summarised in Table II (newman and Condon 1969).

Table II: The Impact of European man on Australia's Arid Grazing Lands Following Settlement.

Vegetation Type	Percentage Land Degradation			
	Little or no Degradation	Minor Degradation	Moderate Degradation	Severe Degradation
Grasslands	30	55	15	Negligible
Shrublands	10	25	40	25
Low Woodlands	40	30	20	10
Spinifex Grasslands	70	20	5	5
Flood Plains	50	20	20	10

Many of the major arid and semiarid land soil groups are characterised by a marked concentration of the major soil nutrients in the upper soil horizon. The loss of this horizon leads to a loss of most of the soil nutrient pool which subsequently limits productivity of the plant community. In addition, seedling growth is suppressed, which results in poor seedling drought survival, so that re-establishment of plants on degraded sites is ultimately reduced. Because of the importance of vegetation in maintaining stability of the soil resource, emphasis on vegetation management is essential if the long term stability of the soil resource is to be maintained! Although species diversity is considered to be a major factor in any consideration of ecosystem stability, as important, if not more important for Australian natural systems, is the maintenance of soil surface stability — particularly where the nutrient pool is accumulated in the surface horizon of the soil. Once the soil surface has been degraded, the chance of the return to a pre-existing biological state will have been greatly reduced (Slatyer 1973).

Ecological Concepts in Arid Land Management

Land degradation processes

As a grazing system is continually over-utilised by stock over the short to medium term, the most obvious effect is the replacement of one type of plant cover by that of another. Grazing changes the botanical composition of a plant community — the heavier the grazing pressure the greater the change. In addition, occurring partially simultaneously with these changes in composition, is the death and break up of perennial grass tussocks and eventually the formation of bare areas (Figure 2). This loss of plant cover is also associated with a decline in forage production.

In grazing terminology, plant communities are composed of both preferred or key species (usually the most palatable and productive species) and undesirable (usually unpalatable) species. In the natural state preferred species predominate. Following over-utilisation of the system through continuous overgrazing, populations of preferred species decrease and voids, or bare areas, increase in size. These voids may be then colonised by undesirable plant species through the process of ecological succession. As the ecosystem is over-utilised the proportion of undesirable species, and hence the degree of land degradation, increases. Changes in botanical composition as well as the loss of plant cover, are the early

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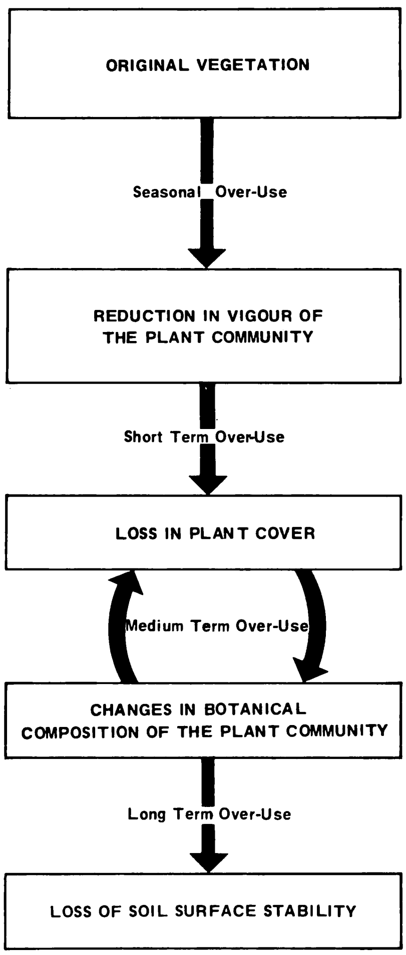
warning signs of land degradation. Recognition of these characteristics as evidence of degradation processes can prevent further deterioration — provided some changes are made to the existing land management practice e.g., re-adjustment of stock numbers. In contrast, severe gully or sheet erosion is the end effect of continued over-utilisation of the grazing system and can often represent a situation where it is either ecologically, or economically, impossible to restore the land. Changes in plant cover and botanical composition are the vegetative indicators of land degradation processes. Complemented with indicators of soil stability, an overall picture of the land condition in relation to the existing climate and management practice can be made.

Figure 2: The processes of land degradation, over time, in a continually over-utilised grazing land system (after Roberts 1981).



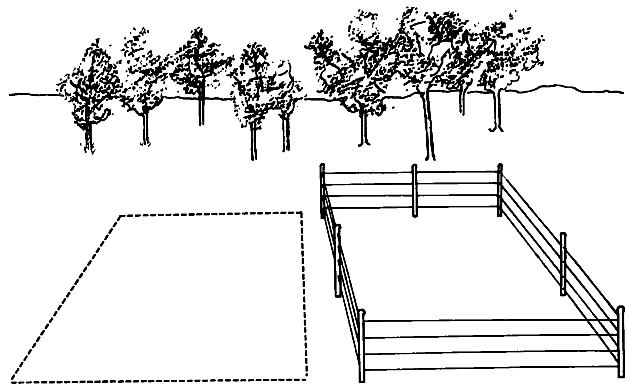
Monitoring of arid grazing lands

Having established that both vegetative and soil characteristics are indicators of land degradation processes, assessment standards can be derived for different grazing land systems.

Detection of any change can be best determined in a monitoring programme. Reference areas, such as the exclosure (Figure 3) provide what is called baseline or check data. They form a standard against which we compare other areas. Exclosures are experimental areas protected from the activities of animals by a barrier such as a fence.

Exclosures vary in size from 0.1 to 2.5 hectares. Monitoring of the vegetation, within and outside the enclosure, allows the direction of trend in plant cover and botanical composition, under the existing climate and management practice. Signals can thus be transmitted to the land manager if there is any evidence of increasing degradation. If a monitoring programme does provide evidence for induced deterioration through over-grazing, then, stock carrying capacity adjustments must be made. Failure to do so will lead to continued deterioration, eventually leading to severe soil loss and finally, loss of economic viability of the grazing enterprise.

Figure 3: An example of a reference area used in a monitoring programme. The reference area is composed of an exclosure, which excludes the activities of man and his animals, and an outside grazed plot.



Primary and secondary production in grazing land systems

By examining the ecosystem process chart (Figure 4) the two central issues in any consideration of grazing land management become evident. Firstly, for any one ecosystem, what is the annual dry matter production per unit area of ground (or net primary production)? By how much does this vary, both seasonally and annually? For any one system, net primary production of the plant community is dependent on factors such as climate (rainfall, temperature) and soil type (soil water storage, fertility). Incoming solar radiation provides energy for photosynthesis. Some energy is lost by respiration by the plant community. However, photosynthesis and net primary production can be limited by shortages of water and soil nutrients, or by unsuitable temperatures for plant growth. Because of wide variability in annual precipitation in arid zones, net primary production fluctuates enormously (Figure 5).

Figure 4: Diagrammatic representation of the principal processes in an ecosystem grazed by animals.

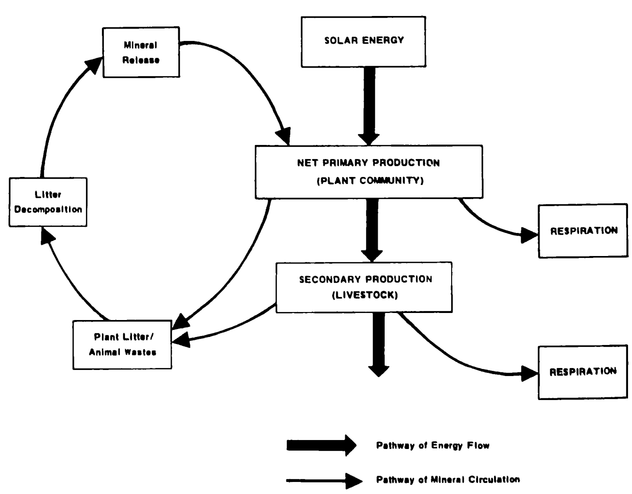


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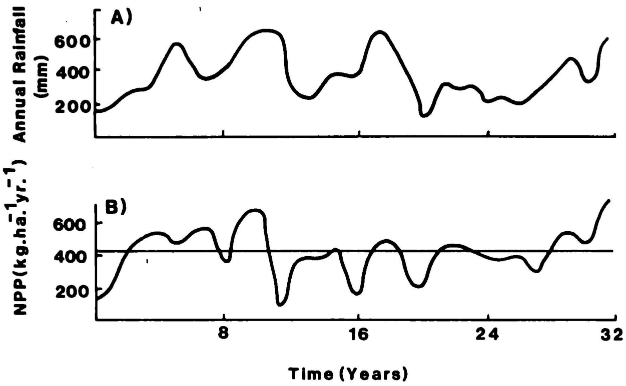
Figure 5: Analysis of historic rainfall figures for Charleville, Queensland using a computer model. Model output shows interrelationships between A) Rainfall and B) Net primary production for a native grassland (Christie 1981).



Arid and semiarid systems are generally regarded as water controlled systems because rainfall has the overriding control on net primary production, relative to the other environmental factors. An 8 to 10 fold fluctuation in annual productivity of a native grassland growing in semiarid Queensland has been recorded (Christie 1981). How well the landholder relates his livestock numbers to the conditions of fluctuating forage supply, each year, will largely control the stability of the grazed ecosystem. In order that yield can be sustained in the long-term, livestock numbers for a nucleus flock or herd should be related to the long-term average net primary production for any one site — not the maximum or minimum value. Furthermore, if the year has high precipitation, small additions to this nucleus population can be made. Similarly, for a very low rainfall year some reduction in the nucleus population must be made! Thus, one important practical management principle emerges for arid grazing lands. That is, livestock populations do not remain constant year in, year out. Annual adjustments should be considered by the land manager in response to the forage supply at the end of the major growing season.

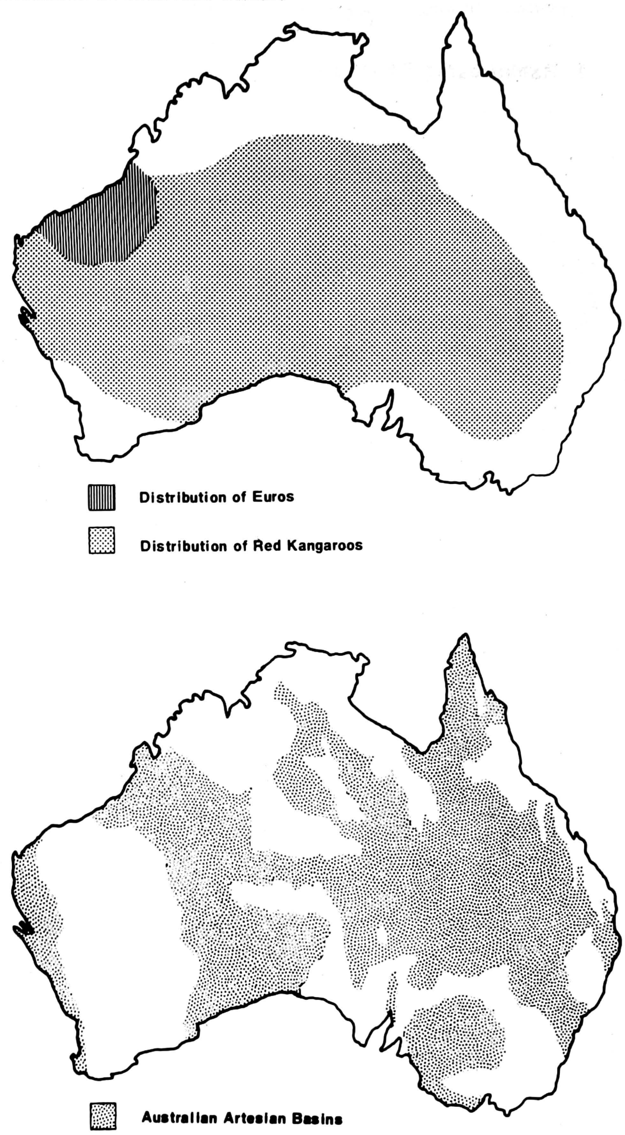
As arid lands are grazed by animals, the next issue to consider is animal production. Secondary production, in grazing systems, generally refers to the production of meat or wool by animals. If we can define the net primary production characteristics, we then need to know how much of this plant material animals may consume each year (Figure 4). The amount of plant material consumed controls not only the production of meat and wool but also ecosystem stability. If the entire amount of annual net primary production is consumed then degradation processes will commence as plant population decline. On the other hand, animal consumption cannot be restricted to a very low level of utilisation, or secondary production will be uneconomic for the landholder. The amount utilised through animal consumption must be based on a balance between ecological and economic factors i.e., soil and vegetation stability is maintained and financial return is near-maximal.

Of the plant material not consumed, some falls to the soil surface and slowly decomposes. This material is part of the litter layer and its pathway is shown in Figure 4. The litter layer has a significant role in mineral circulation. The presence of litter is also important in providing a micro-habitat for seed germination in arid lands and in improving infiltration of water into soil. The scientific basis for managing arid grazing lands should be the maintenance of a balance between the living vegetation, the dead vegetation and the soil, in order to maintain long-term stability. This is another important management principle for arid grazing lands.

Interrelationships between domestic livestock and wildlife

The distribution of kangaroo populations in inland Australia has been significantly affected by the use of artesian water by the pastoral industry. Artesian water is reticulated from the borehead by shallow ditches (called bore drains) or into troughs. By these methods the range and abundance of some native marsupials was greatly extended as they were no longer restricted to permanent water courses. The distribution of the red kangaroo is one example of range extension due to the use of artesian water (Figure 6). Some grazing effects of domestic livestock are also beneficial for kangaroos. Close grazing of vegetation by livestock induces the plant to produce green shoots which, in turn, encourages consumption by kangaroos (Newsome 1971). In the Pilbara district of Western Australia euros have considerably outnumbered sheep since the 1930's and have been blamed for the decline of the sheep industry and red kangaroo populations in this region (Ealey 1972) (Figure 6).

Figure 6: Distribution of red kangaroo populations in arid and semiarid Australia, the district where the euro is regarded as a pest (Newsome and Corbett 1977) and location of artesian water.



The effects of such factors as clearing of land for agriculture, the deterioration of grasslands by continuous livestock grazing and predator losses have resulted in the situation today where four out of a total of about 120 marsupials are probably extinct. Several more are close to extinction and perhaps about twenty are endangered. A more general effect is a drastic reduction in range since European settlement; some examples for arid wildlife species are shown (Figure 7). The reduced status of these marsupials is an indication of habitat changes in arid grazing lands (Newsome and Corbett 1977).

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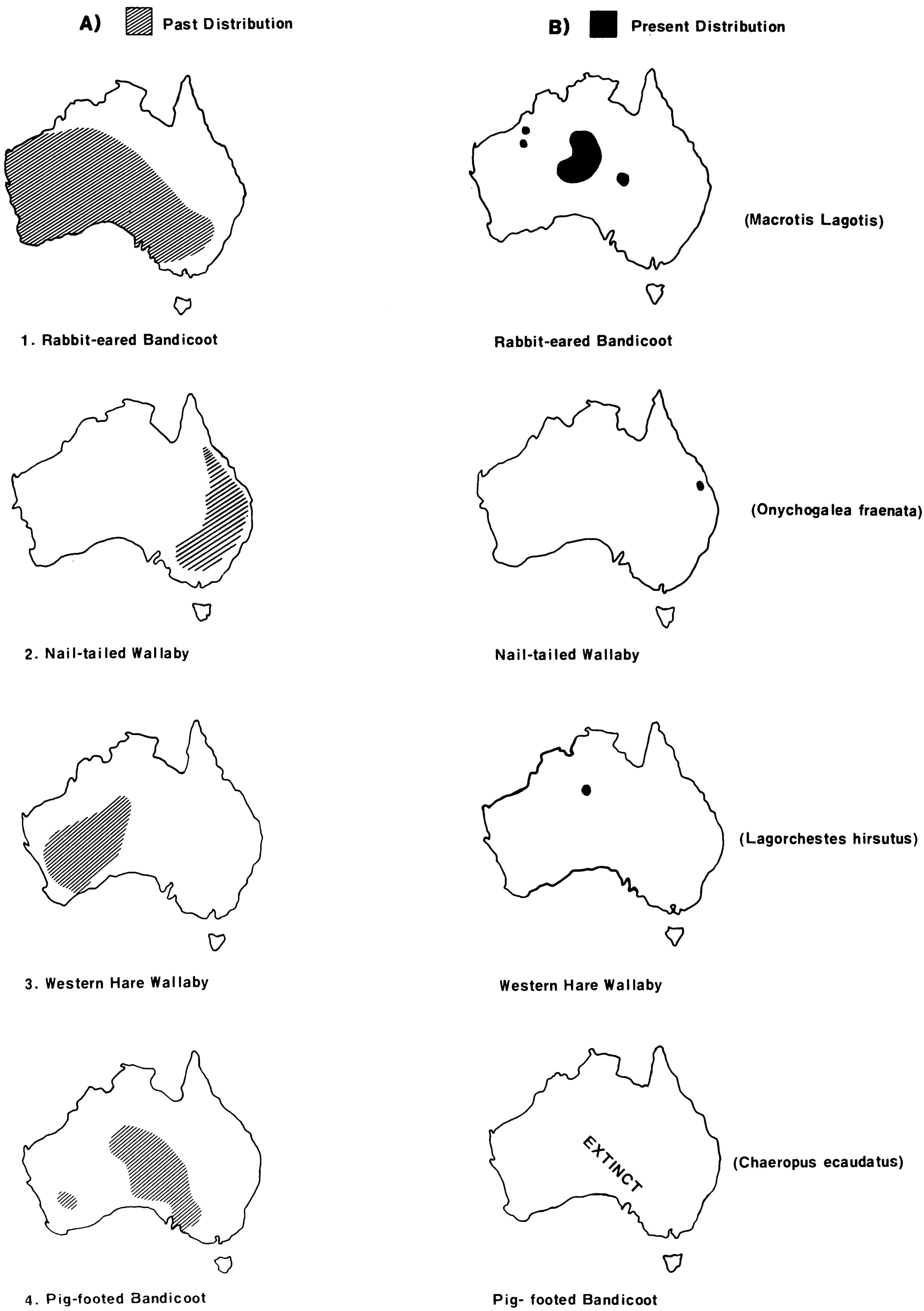
Figure 7: Past and present distribution of some native marsupials from the arid and semiarid zone A) Past distribution and B) Present distribution (adapted from Newsome 1971; Gordon and Lawrie 1980).



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Of the feral animals introduced to Australia, rabbits are by far the worst pastoral pest. Their present limits of distribution were reached about 1900 after they were taken inland from Melbourne in 1859. Rabbits graze land bare, ring-bark trees, dump sub-soil on the surface and induce erosion. An unchecked plague over a two-year period can lead to a significant decline in livestock production (Newsome and Corbett *op. cit.).* Apart from competing with domestic livestock for forage, feral animals represent a serious threat as potential reservoirs for diseases of domestic livestock. Feral animals such as pigs, buffalo, donkeys, camels, horses and goats extend over a wide range of northern tropical Australia as well as arid and semiarid Australia. Australia is relatively free of exotic diseases. However, if an exotic disease should invade, its spread would be aided by feral livestock (Newsome and Corbett *op. cit.).*

Serious diseases not present in Australia, but which would have disastrous effects on the grazing industry, include Foot and Mouth Disease (present in Indonesia) and Blue Tongue Disease (India, Africa). Control or eradication of feral animals is essential for sustained domestic livestock production.

Future Needs

What steps can we take to ensure that future degradation of arid lands is minimal? In many situations the size of the pastoral holding in Australia's arid lands needs to be increased. Insufficient size of the pastoral holding has contributed to past overstocking and degradation of Australia's arid grazing lands. Ebersohn (1973) believes that the biggest single manipulative practice possible for Australia's arid lands for their continued productivity is an increase in the size of the pastoral holding. This issue remains a major challenge for land administrators. Any consideration of what is a suitable living area for a pastoral holding depends on what value constitutes an economic flock or herd size and, as well, a scientifically derived value for livestock carrying capacity. Because of the wide variability in annual precipitation in arid and semiarid environments, carrying capacity values for different vegetation types need to be based on the annual variability in net primary production as well as the degree of herbage utilisation through consumption by livestock. How well the land managers adjust livestock numbers to a fluctuating supply of plant material will determine the stability of the grazing land system and their financial return. Although most of the past research into animal ecology has concentrated on domestic livestock, much more study into the interaction between domestic livestock and wildlife populations needs to be undertaken. Finally, there need to be broad educational programmes, so that people are better aware of the processes of land degradation as well as the appropriate scientific concepts for managing arid lands.

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REFERENCES

Christie, E.K. (1981). Ecosystem processes in natural grazing lands: their application to the estimation of animal carrying capacity *In* Christie, E.K. (ed.). *Desertification of Arid and Semiarid Natural Grazing Lands.* Australian Development Assistance Bureau International Training Course, Brisbane, Australia. July 1981. pp 108-122.

Dregne, H.E. (1978). Desertification: Man's abuse of the land. *Journal of Soil and Water Conservation, 33,* 11-14.

Ealey, E.N.M. (1962). Biology of the euro *Macropus robustus cervinus* (Thomas) Ph.D. Thesis, University of Western Australia.

Ebersohn, J.P. (1973). Environmental limitations and their role in the stability of low rainfall grazing lands and grasslands. *Proceedings Third World Conference on Animal Production, 1,* 2(d) 6-2(d) 8. Melbourne, Australia.

Gordon, G. and Lawrie, B.C. (1980). The rediscovery of the bridled nail-tail wallaby *(Onychogalea fraenata* Gould) in Queensland. *Australian Wildlife Research, 7,* 339-345.

Moore, R.M. and Perry, R.A. (1970). Vegetation of Australia *In* Moore, R.M. (ed.). *Australian Grasslands,* A.N.U. Press, Canberra pp 59-73.

Newman, J.C. and Condon, R.W. (1969). Land Use and Present Condition *In Arid Lands of Australia* R.O. Slatyer and R.A. Perry (eds.) A.N.U. Press, Canberra.

Newman, A.E. (1971). Competition between wildlife and domestic stock. *Australian Veterinary Journal, 47,* 557-86.

Newsome, A.E. and Corbett, L.K. (1977). The effects of native, feral and domestic animals on the productivity of the Australian rangelands *In The Impact of Herbivores on Arid and Semiarid Rangelands,* Australian Rangelands Society, Perth. pp 331-356.

Perry, R.A. (1966). The need for rangelands research in Australia. *Proceedings Ecological Society of Australia, 2,* 1-14.

Perry, R.A. (1970). Arid shrublands and grasslands *In* Moore R.M. (ed.) *Australian Grasslands* A.N.U. Press, Canberra, pp 246-59.

Roberts, B.R. (1981). Range condition and trend assessment *In* Christie, E.K. (ed.). *Desertification of Arid and Semiarid Natural Grazing Lands.* Australian Development Assistance Bureau, International Training Course, Brisbane, Australia. July 1981. pp 132-140.

Slatyer, R.O. (1973). Structure and function of Australian shrublands In Hyder D.M. (ed.). *Arid Shrublands,* Society for Range Management, Denver, U.S.A. pp 66-72.

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