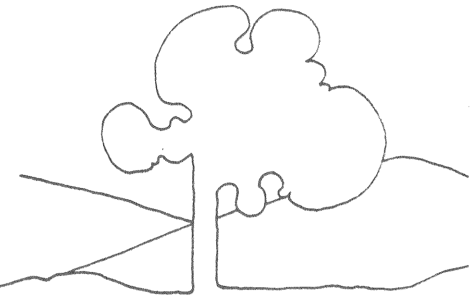
Ecological studies in pasture condition in semi-arid Queensland



B.R. ROBERTS, CHARLEVILLE DECEMBER, 1972

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ECOLOGICAL STUDIES ON PASTURE CONDITION IN SEMI-ARID QUEENSLAND

by B.R. Roberts*

Second Printing

Due to continued requests for this publication a second printing has become necessary. The field site photographs which appeared in the 1972 edition have not been reproduced here. Site photographs are held at the Charleville Pastoral Laboratory and Agriculture Branch, Brisbane. The cover has been changed and minor corrections have been made in the text and 'Literature Cited'.

Some sections of the report have been published elsewhere and readers are referred to:-

Roberts, B.R., Graham, T.W.G., and Orr, D.M. (1976). Quantitative floristic studies of the ground layer in some mulga (*Acacia aneura* F. Muell.) and Mitchell grass (*Astrebla* spp.) communities in south-western Queensland. *Aust. J. Bot.* *24*: 743-52.

Orr, D.M. (1975). A review of *Astrebla* (Mitchell grass) pastures in Australia. *Trop. Grasslds* *9*: 21 - 36.

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"The conquest of the Australian inland demanded fortitude and endurance, self-reliance and faith; nor did the need for these qualities disappear when the conquest had been achieved.... Australians have every reason to be intensely proud of their record in settling the great spaces of the inland. They are to be blamed only in that they seem to have done the job too thoroughly."

F.N. Ratcliffe

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PART II: INVESTIGATIONS INTO THE LOCAL APPLICATION OF PASTURE CONDITION ASSESSMENT

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To all these co-operators the writer wishes to express his sincere thanks.

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INTRODUCTION

This report is primarily concerned with the examination of the condition of the natural grazing lands of western Queensland and with the evaluation of the possibilities of grazing land management in this region. As may be seen from the table of contents, this study has been divided into

(i) describing the resources concerned,
(ii) examining the evidence on deterioration and its causes,
(iii) introducing the concepts of condition and trend,
(iv) establishing local standards of condition from field survey data, and
(v) considering the needs for and possibilities of grazing land management in the semi-arid areas of Australia.

Under the circumstances in which this study was undertaken, the writer has chosen to draw conclusions on the basis of collated findings and opinions of experienced Australian field workers, rather than attempt to personally judge the complex situation in the limited time available to gain field experience. The exception to this is the section of the report which deals with the drawing up of local condition standards, an aspect of research which has not been previously attempted in semi-arid Australia.

The final section, on research needs, arises from the evidence quoted in earlier sections of the report and is limited only to the vegetation maintenance facet of semi-arid research needs.

A. MULGA COUNTRY OF SOUTH-WESTERN QUEENSLAND

1. Geographical area and physical environment

The south western division of Queensland comprises approximately 22 million hectares of natural grazing lands dominated for the most part by Acacia aneura (mulga) and is able to maintain between 4 and 5 million merino sheep (Burrows and Beale, 1970).

The landscape is derived from the mesozoic sedimentary formations which form the Great Artesian basin. The soils of the area have been described by Isbell et al (1967) and Christie (1970). In general, mulga soils vary from red sandy loams to loams with an acid reaction (pH 4.0-6.0) and poor physical and chemical characteristics. Lateritic red earth is the predominant soil group supporting mulga. The combination of rapid surface sealing, very poor structure, poor water holding capacity, strongly acidic reaction and low levels of both phosphorus and nitrogen, results in generally low soil productivity, which is aggravated by poor seedling establishment conditions and high runoff of the limited precipitation. On the basis of Northcote's (1967) broad soil groupings for south western Queensland, the major soil mapping unit (My 1) is "Neutral Red Earths (Gn 2.12) mantled by siliceous and/or ironstone gravels". Next most widespread is the unit CC 19 designated "Grey clays (Ug 5.24, 5.25) and brown clays (Ug 5.38, 5.39), the dominance of grey and brown clays varying locally". The third major unit is dissected hill country classified as unit F z1 in which the chief soils are "Shallow Loams (Um 1.43 and Um 5.41) usually containing or covered by siliceous gravel, with many rock outcrops and boulders of siliceous or ferruginous materials". Related to the unit My 1, is the soft red earth referred to as My 4 and consisting of sandy and loamy red earths (Gn 2.12 and Gn 2.13). For the sake of simplicity the terms lateritic earth, cracking clay, rocky plateaux and sandy red earth will be used for the above major soil units of the mulga region.

Farmer et al (1947), using Blake's (1938) data, compared the vegetation, climatic and soil maps of western Queensland and concluded that, "The general pattern of vegetation types (grassland, woodland, etc.) depends primarily upon soil differences, though climate influences the floristic composition of the major plant formations".

Topographically, the mulga country may be differentiated into runoff and runon areas. As a rule the more favourable runon areas support either a form of groved mulga where local accumulation of water is slight, or other communities such as gidyea (Acacia cambagei)or Mitchell grass (Astrebla spp.) where heavy clay soils occur. Although these last-named communities occur as local enclaves within the mulga geographical region, they are ecologically distinct from the mulga and are thus described separately under "Mitchell grass country".

The climate of the mulga country is semi-arid, the average annual rainfall varying generally between 10" and 20". The seasonal distribution of the rainfall varies with latitude; in the southern extremity of the Queensland mulga country, approximately half the annual rainfall falls during winter. The winter component of the rainfall is important from a grazing point of view and is responsible for a good growth of non-grasses ("herbage") fodder plants during the winter. Both the winter component of the rainfall and the associated herbage growth decrease to the north and at the northern limits of the mulga country only a very small proportion of the annual rainfall falls during winter (Fitzpatrick and Nix, 1970).

High summer temperatures for extended periods (mean max. of 96°F for 3 months) result in high evaporation rates and correspondingly lowered efficiency of moisture use (Christie, 1970). The fact that a high proportion (75%) of the rain falls in the form of thunderstorms adds further to the low efficiency of the rainfall through its effect on runoff (Brunt and Hogan, 1956). Relatively high radiation rates of 300 cal cm^{-2} day^{-1} in mid-winter and 620 cal cm^{-2} day^{-1} in mid-summer also contribute to high moisture loss and lower plant production.

2. Variability of precipitation in Queensland and its influence on grazing land

It is generally accepted that western Queensland has a climate which is characterized by wide extremes of wet and dry years. In the definition and use of plant successional stages in dynamic ecology, the comparative roles of climate variation and management need to be distinguished.

A search for evidence on the relative variability of annual precipitation in Queensland as compared with similar homoclimes elsewhere in the world indicates that Queensland is subject to more widely varying precipitation than other comparable rainfall regions of the world.

Using such measures as the "coefficient of variation around annual mean rainfall", it can be shown that that portion of Australia lying between 20° and 30° S has a higher variability than areas of similar rainfall elsewhere (Nix, 1972). Among the authors who have examined this phenomenon, Conrad (1941), Loewe (1948), Molnar (1948), Leeper (1960), Troll (1964), Fitzpatrick and Nix (1970) and Gentilli (1971) all supply evidence which supports the conclusion that, by world standards, most of the eastern half of the Australian continent is subjected to a more variable annual precipitation than occurs elsewhere in similar total rainfall belts. Leeper (1960) has prepared maps which indicate that western Queensland has an annual mean rainfall variability which is 10% greater than the "world standard variability". In an earlier analysis of Conrad's (1941) relative variability data, Leeper (1945) states that the pastoral belt with 15 - 25" rainfall running north and west from New South Wales through Queensland and the Northern Territory is from 10 to 20% more variable than elsewhere and "appears to be more unreliable than any large region of similar rainfall in the world". Davies (1955) states that over the whole of the arid zone, the mean variability of rainfall exceeds 30% of the world mean variability. Dick (1958) has given a detailed analysis of the variability of the rainfall of Queensland and has related this above-normal variation to natural plant communities of the state: "In striking contrast to exotic crops and pastures, the indigenous communities appear well adapted to withstand the marked and extreme fluctuations in rainfall that occur. Xerophilous characteristics are pronounced, and as a consequence, the plant communities are normally unaffected by adverse rainfall conditions in any one year. The native grassland communities of Western Queensland, however, are interesting exceptions. Conspicuous changes in the abundance of annual and ephemeral plants are common and often reflect the large-scale variations in rainfall which are characteristic of the grasslands". Blake (1938) has indicated how fluctuating dominance among perennial grasses may be associated with such climatic variations, e.g. the more drought-tolerant Astrebla communities may be dominated by Dichanthium after a series of good years.

In terms of animal production the effect of variable climate is demonstrated by Ebersohn's (1970) example from south western Queensland in which, with static sheep numbers and management, rainfall variation alone was responsible for an increase of 53,000 lb greasy wool over a two year period. Heathcote (1964), in the most searching examination of production problems of Warrego country, highlights the central role of variable climate in fodder production: "All the evidence of the sequence of droughts and good seasons suggests that the true character of the plains environment is not to be interpreted in terms of a balance but in terms of fluctuating conditions, now good, now bad......Official policies have not recognized this and have tried to impose here policies which have had only limited success in the areas for which they were more suited, namely the more humid east".

Everist and Moule (1952) have summarized the general effects of seasonal climate on botanical composition as follows: "Rain in summer brings up species other than the perennial grasses and these fill the interstices between the perennial tussocks. They may be either annual plants (including grasses) or plants with perennial roots which produce annual stems. Rain at other periods may bring up other plants, mainly annuals with a short life cycle. The actual species depend upon locality, soil and time of year, as well as the amount of rain received. Variation in one or more of these factors results in marked differences in floristic composition". These authors cite a significant example of floristic changes following abnormal rainfall patterns; During the decade ending 1943 many years' summer rainfall was below normal while rain at other seasons was above average. This apparently caused the spread of Bassia birchii (Galvanized burr) at the expense of perennial grasses. Abundant summer rain for the three years ending 1950, "markedly reduced" the burr and restored the dominant perennial grasses, "except where other factors such as overgrazing had operated to prevent the re-establishment of the perennial pasture.......The density of plant cover varies from place to place and from year to year and at present no quantitative expression of this factor is possible" (Everist and Moule, 1952).

Farmer *et al* (1947) maintain that the components of climate, in conjunction with pasture and soil types, control the plane of nutrition of sheep. Apparently the possible role of ecologically-based management is discounted as a factor influencing production. Everist and Moule (1952) state that the fodder likely to be available depends upon the nature of the vegetation, the condition of the pasture and the grazing pressure. These authors have indicated the close interaction between climate, vegetation and grazing animals: "Climatic changes affect both vegetation and grazing animals; changes in vegetation affect microclimate as well as animals; and changes in the numbers and the kinds of animals produce changes in the vegetation".

In considering the overriding role of climate in western Queensland, the classic investigation of the effects of drought on the basal cover and botanical composition of semi-arid grazing, reported by Tomanek and Hulett (1970) for the Central Great Plains of North America, may be considered. On the basis of weather records of 100 years starting 1868, it was shown from documented areas near Hays, Kansas, that basal cover decreased from 85% before serious droughts to less than 20% when the droughts broke. Production varied from 900 lb/acre to 4,100 lb due to climatic fluctuations only. The accumulative effect of intensive grazing in drought conditions is shown by Albertson *et al* (1957) in the same area. Their studies exposed a loss of more than 90% of the original basal cover after heavily grazed grassland had been droughted from 1952 to 1956.

In Australia a number of studies have been undertaken to ascertain the floristics and density of "pristine" or ungrazed vegetation. In drier regions, studies of Jessup (1951) in South Australia and Lange (1966) in Central Australia are of most interest. Both these studies indicate that even on ungrazed reference areas, considerable decrease in shrub density occurred presumably as a result of drought.

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Apart from the unpredictability of the rainfall, the efficiency with which it can be used for fodder production is very important. To illustrate the low efficiency of the rainfall on arid deep red earths, Winkworth's (1970) results may be quoted. In Central Australia, over a two year period, it was established that in arid vegetation dominated by Acacia aneura, Eragrostis eriopoda, Neurachne mitchelliana and Danthonia bipartita, only 52% of rainfall entered soil storage, 28% ran off and 20% was directly evaporated.

In conclusion it should be added that, as was shown over a ten year period ending 1934 (Trumble and Cornish, 1936), irrespective of grazing treatment, rainfall variability has a marked effect on annual productivity of natural grasslands, even in the reliable winter-rainfall regions.

3. Vegetation

a) General floristics and affinities

The most detailed of the many descriptions of the vegetation of western Queensland is given by Blake (1938).

The most common tree is Acacia aneura but a number of other trees are important in the mulga country of this area. Of these Eucalyptus populnea and E. terminalis are the most common, with E. melanophloia also of general occurence. In addition to the above, Acacia excelsa, Hakea ivoryi, Eremophila mitchellii, Myoporum deserti, Grevillea striata, Brachychiton populneum, Eremophila gilesii and Cassia pleurocarpa are also important woody constituents.

The ground layer consists of varying proportions of grasses and non-grasses as indicated in the survey results section of this report. It may be seen that the grass genera Aristida, Amphipogon, Neurachne, Chloris, Eragrostis and Tripogon are the most common, while the "herbage" genera Sida, Bassia, Portulaca, Kochia, Ptilotus, Atriplex, Goodenia and Evolvulus make up the greatest proportion of the non-grasses.

In terms of general affinities, the vegetation of this area is part of the Eremaean zone which covers the whole of arid Australia and which is characterized by "extreme variability of the rainfall both annually and seasonally" (Burbidge, 1960). The origin of the Eremaean flora is of particular interest, having evolved via more complex routes than is the case with the Temperate and the Tropical flora. Important genera of the Eremaean flora are Ptilotus, Phyllanthus, Dodonaea, Eremophila, Goodenia, Helipterum and several Compositae. Referring to the mulga zone, Burbidge (1960) states, "Apart from the discontinuities which indicate past climatic and floristic changes, the flora of the Eremaea has certain features which suggest that many of its characteristic elements may be of relatively recent development. The flora exhibits a curious mixture of uniformity and variability. Thus the species Acacia aneura F. Muell. (mulga) occurs throughout much of the southern and central portions, especially where the rainfall varies in both annual volume and seasonal occurrence. The general representation of species in association with it changes comparatively little over many hundreds of miles".

Crocker (1959) suggests that the evidence from Quaternary times indicates that the onset of the prehistoric arid period was "sudden and drastic" and that the main refuges of the flora during that time would have been the mountains, water courses and rivers.

b) Structure and dynamics in relation to management and climate

The mulga formation exhibits an important relation between tree density and ground layer productivity. The structure of the vegetation may vary from a closed forest of tall mulga, with an almost complete absence of ground layer plants, to a treeless open grassland in which grasses form a relatively dense and productive community. The degree to which either of these extreme forms of structure or any of the range of intermediate types of woodland develops is dependent on soil type, conditions favourable to mass germination, long term rainfall, fire, browsing pressure and artificial clearing of trees. The interaction of these controlling elements on each other and on the inherently unstable vegetation makes for an unusually complex and dynamic ecological situation.

A considerable volume of research has been published on the relationships between tree density and productivity of the mulga community as a whole. Significant contributions in this field are those of Everist (1949), Wilcox (1960), Perry (1970), Slatyer (1965), Ebersohn (1970), Burrows and Beale (1970). Beale (1971) has indicated general relationships in a comprehensive review of world literature on tree:grass manipulation techniques.

Many writers have referred to the possible changes in botanical composition which may result from overgrazing, clearing, fire or drought in mulga country (See under "Deterioration") and Holland and Moore (1962) have proposed details of a seral retrogression in denuded mulga scrub in the Bollon area:

Acacia aneura, *Eucalyptus exserta*, *Brachychiton populneum*, *Eucalyptus thozetiana*, *Acacia excelsa*

↓

fire, lopping, overgrazing

↓

Eragrostis lacunaria, *E. eriopoda*, *Neurachne mitchelliana*, *Digitaria ammophila*, *D. brownei*, *Enneapogon nigricans*, *Paspalidium gracile*, *Dodonaea attenuata*, *D. boronifolia*, *D. viscosa*, *Eremophila latrobei* (or on skeletal soils *E. gilesii* and *E. bowmanii*).

Blake (1938) lists as pioneers in stock routes on sandy soils Bassia birchii, B. bicornis, B. quinquecuspis and the annual grasses Enneapogon, Tragus, Perotis and Aristida. Where soils are level, fertile and not easily eroded, destruction of the original climax is not necessarily a detrimental process, and Lange (1972) has recently pointed out that such a disclimax may in fact be more productive than the original vegetation.

Instances of well-documented regeneration patterns in semi-arid Australia are few. A noteworthy case is that of the Albert Morris Park at Broken Hill N.S.W. (9" rainfall) as reported by Pidgeon and Ashby (1940). Based on the simple assumption that the exclusion of animals (including rabbits) would permit regeneration of the native plant cover, protection of the area concerned for two years had a number of beneficial effects:

(i) the growth of individuals present before fencing was markedly increased,

(ii) the density of perennials was increased,

(iii) the three most undesirable species (Malva, Lotus, Argemone) were decreased.

(iv) the density of annuals was reduced by competition from robust perennials,

(v) the variety (number) of annual and perennial species was increased.

The success of the Broken Hill regeneration project contrasts strongly with the notable lack of success of a similar project at Koonamore (8" rainfall) in semi-arid South Australia (Wood, 1936). In the latter case, twelve years of protection did not restore the perennial flora, but maintained only a fluctuating population of annuals and short-lived perennials. This poor response was attributed to subnormal rainfall, grazing by rabbits and the eroded condition of the land prior to fencing.

The availability of quantitative floristic data on more semi-arid sites is an important factor in developing an understanding of the reaction of grazing land, not only to protection, but also to use of known intensities under recorded environmental conditions.

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Beadle (1960a) maintains that in New South Wales, the removal of Acacia aneura leads to the dominance of woody weed genera such as Cassia and Dodonaea (and Eremophila (James, 1960)) due to adverse microhabitat conditions. If it is assumed that mulga forest or open woodland is the climax community of the mulga country, then it must be accepted that no cleared or drastically thinned area will remain in the grassland stage permanently without the application of some agency such as browsing or fire to keep the tree population from regaining its former dominance. In practical terms, management may aim at the almost impossible goal of grazing heavily enough to control the ascendency of tree seedlings over grass and simultaneously to avoid overgrazing and eventual elimination of the desirable perennial grass population.

c) Productivity, nutritive value and carrying capacity

The productivity of mulga country has been shown by many writers to vary with seasonal rainfall, tree density and condition of the vegetation as affected by past management. The important role of mulga as a drought feed complicates the formulation of simple recommendations and leads to a situation in which the manager is faced with the dilemma of this useful fodder tree becoming so dense and tall that, at least in Queensland, it can completely eliminate an otherwise very useful ground layer of grasses and herbs. (This problem will be dealt with in detail under "Management".)

In terms of overall productivity and stocking rate, McTaggart in 1936 recorded a carrying capacity of 1 sheep to 5 acres for the mulga country of south western Queensland. Today most of this area is rated at 1 sheep to 7 or more acres by the Lands Department.

Clearly the absolute yield of grazable material produced by a given tree density on a specific soil type, will fluctuate widely with variations in seasonal rainfall. Over carefully monitored experimental periods covering a number of seasons, several workers have quantified the yield of leaves from mulga and the associated ground cover yield. In the absence of stocking rate trials, potential carrying capacity can best be estimated on the basis of measured production of forage by the mulga community as a whole.

In Beale's (1971) studies, the forage and litter production from trees and ground cover were examined and the results of these studies and those of Burrows (1971) suggest that the net productivity of woody communities of this area is unlikely to exceed a maximum of 0.25 $g/m^2/day$. Working on the basis of 50% removal by grazing animals, Beale (1971) estimated that approximately 140 kg/ha/annum were available for animal consumption in mulga country, the balance of the net production being left as standing growth. (Ebersohn (1970) gives a figure of approximately 600 kg/ha for a single autumn harvest in cleared mulga in the same area.) Converting the above available fodder production to stocking rate, Beale (1971) estimates that since a sheep requires approximately 460 kg of dry matter per annum, a stocking rate of 1 sheep to 3.3 ha (8.2 acres) is obtained for areas with a relatively sparse tree cover and without the lopping of mulga as a supplement. Denser trees and below average rainfall require lighter stocking than the above figures.

Finally, it should also be emphasized that most of the mulga country of south western Queensland has a considerably lower rainfall than the Charleville area in which the above quantified results were obtained and thus the above productivity should be considered as a maximum rather than a norm for the region.

d) Optimum tree density in mulga country

It has been suggested by Everist (1949) that a compromise between productive ground cover and reserve fodder trees may be attained at a tree density of 175 trees/ha in areas receiving 500 mm of rain annually. In applying such a rule of thumb several complications arise, most of which result from the change of the mulga population with time and the partial independence of tree increase from management. In addition, in general terms it may be accepted that the lower the average annual rainfall, the more dependence is placed on mulga as a natural supplement. Conversely, the opportunities of developing (and relying upon) a productive ground cover increase with increased rainfall, i.e. towards the eastern limits of the mulga country.

Furthermore, a clear distinction needs to be made between mulga on hard lateritic soils with high runoff and mulga on soft sandy soils which generally display considerably better moisture relations than the former soils do.

Beale's (1971) established quantitative relations between tree density and herbage yield of the ground cover indicate that even at low densities, trees have a serious effect in reducing herbage yield. Thus, while Everist's above-mentioned optimum tree density aims to include a built-in drought reserve, it may be expected to reduce the available grazing considerably.

It should be stressed that many practical examples have indicated that the thinning or clearing of mulga on certain soils has led to an ecologically significant and economically important increase in undesirable plants ranging from large shrubs such as sandalwood (Eremophila mitchellii) to smaller woody weeds (e.g. turkey bush (Eremophila spp.)) and problem grasses like wiregrass (Aristida jerichoensis) to name but a few.

This increase in undesirables in thinned mulga country is perhaps not simply the result of less competition from mulga per se, but is possibly the culmination of long periods of selective grazing which have reduced the source of seed of most of the palatable perennial grasses which would normally fill an ecological niche of this kind. Although not in mulga country, Hall, Specht and Eardley (1964) recognize this factor when presenting a retrospective evaluation of the lack of regeneration of the Koonamore reserve in South Australia. They enumerate the requirements for natural reclamation of degraded vegetation: "Regeneration is only possible if

(1) there are (seed) source plants present in the area;
(2) the species flower and fruit readily;
(3) the seeds remain viable until a season favourable for germination occurs;
(4) seeds have a high germination rate;
(5) there is a suitable seedbed for establishment, and

(6) the seedlings are relatively unpalatable to introduced animals such as sheep and rabbits."

No doubt the possibility of manipulating grazing animals may modify the last requirement mentioned by these authors.

Attempts to develop a desirable tree:grass ratio in mulga country have met with mixed success. While several cases of successful regeneration of mulga from seedlings through spelling are on record , many cases may be found in which an almost complete lack of regeneration has been experienced in the same area and under similar treatment. On the other hand, Moore and Walker (1972) have been able to demonstrate that, at least under the conditions prevailing in semi-arid southern Queensland during the period 1968-71, ecologically-based animal management after tree thinning can lead to an improved grass cover, which in turn is associated with a considerably lower tree seedling (Eucalyptus populnea) population. This work emphasized the importance of heavy intermittent grazing. The work of Wilcox (1960) in arid Western Australia indicates not only that cleared mulga land yields more grazing than uncleared land does, but that this increase in yield is due to a change from annual grass (Aristida contorta) to perennial grass. Wilcox, however, qualifies these results by adding that clearing "would probably be useful only in areas where soil conditions favour the growth of perennial grasses and shrubs".

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B. MITCHELL GRASS COUNTRY OF WESTERN QUEENSLAND

(from a review by D.M. Orr)

1. Geographical distribution and physical environment

The Mitchell grasses (Astrebla spp.) are endemic to Australia and are restricted to inland areas of the continent where they are best developed between the 10 25" isohyets. The major areas occur in western and north western Queensland and also on the Barkly Tableland in the north east of the Northern Territory. The genus is restricted almost exclusively to the grey, brown and red cracking clay soils.

Two main types of topography support Astrebla grasslands in Queensland. The more extensive type is the rolling downs consisting of low hills with long slopes and shallow gullies. These areas are usually treeless or almost so. Such areas occur on soils developed from cretaceous sediments of limestone or calcareous mudstones or sandstones. The second type is the level plains derived from ancient alluvial sheets along some of the inland rivers, e.g., the Warrego (Everist, 1964).

Despite the diverse origin of these two soil types, they are remarkably similar. One difference lies in surface profile. Everist (1964) reports that the top 6" of a Mitchell grass soil near Blackall consists of a self-mulching clay while Allen and Roe (1943) report that at "Gilruth Plains", Cunnamulla, Queensland, the surface 6" is a well structured clay containing a relatively high proportion of fine sand. Apart from this difference in surface, soils from both origins show great similarity. Beneath the surface each shows a zone of clay which has massive structure and towards the bottom of this zone a slight accumulation of lime occurs. Because of the shrinking on drying, these soils crack at the surface. These cracks are 2-3" wide at the surface and extend down in rough polygonal columns almost to the bottom of this massive structured clay zone at about 30" on the sedimentary soils and at 20-24" on the alluvials. Below this zone, both soils tend to heavier clays and gypsum with less tendency to crack.

The soils of the rolling downs can be subdivided on the presence or absence on the surface of pebbles derived from

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the old lateritic sheets. Where these pebbles occur (the "pebbly downs") admixture of red with grey has occurred such that a brown soil of slightly lighter texture is produced with consequent less tendency to crack. Where these pebbles are absent the soil is referred to as the "ashy downs".

The fertility status of these heavy clay soils varies considerably. Although nitrogen is relatively low, extended dry spells between and within seasons and the accompanying "flush" of nitrogen resulting from microbial action ("Birch effect") would ensure satisfactory nitrogen levels for growth. The soils are reasonably well supplied with potassium, while both calcium and phosphorus are variable. Under most circumstances, however, mineral nutrition is not the limiting factor in vegetation growth in these regions.

As has already been described in the mulga region, the highly variable rainfall is the overriding feature of the environment also in the vast Mitchell grass plains. The effect of rainfall on dry matter production is illustrated by Winders (1936) who states, "Of all the climatic factors whose variations are responsible for the changes in behaviour of Mitchell grasses, that of precipitation shows the highest correlation with growth characters. Variation in factors such as temperature, evaporation and wind strength produce changes in behaviour of grasses, but none comparable with the vicissitudes from year to year and from season to season of rainfall". (For a full discussion of effect of rainfall see under "Dry Matter Production".)

Because of this rainfall variability, droughts are an overriding factor in primary production in the region. Droughts may be brought about by either, or by a combination of two separate drought types. The more common drought in the Mitchell grass area is that which is made up of a succession of mediocre years in which pasture production is low. The other type of drought is the single very dry year. The effect of the latter drought may not be as disastrous as the former, as reduction in livestock numbers and/or loss of production can be alleviated in the following good seasons (Everist and Moule 1952).

With soil moisture the limiting factor in pasture production, it is important that infiltration of all rainfall occurs so that maximum pasture production can be obtained. Allen (1963) showed that runoff was "practically nil" when 7.61" fell over six days on a heavily cracked clay soil at "Gilruth Plains"; however, rain more frequently occurs in short duration falls of high intensity such that runoff occurs in a number of cases.

2. Vegetation

a) Floristics of the Mitchell Grass Association

In a stable condition a Mitchell grassland community consists of an even, sparsely distributed stand of Mitchell grass occupying up to 5% basal cover with one or more of the four species being present. Other perennial grasses include Dichanthium sericeum, Eulalia fulva and Eragrostis spp. with other perennials occurring locally, e.g., Aristida latifolia in the Blackall area. The bare ground between these tussocks provides living space for a variety of other plants, both annual and perennial gramineous and non-gramineous Some of these more important plants include Iseilema spp., Dactyloctenium radulans, Panicum whitei, P. decompositum, Sporobolus caroli, S. actinocladus, Chloris spp., Eriochloa spp., Boerhavia diffusa, Portulaca sp. aff P. oleracea, Chenopodiaceae, Rhynchosia minima, Glycine falcata, Psoralea spp., Crotalaria spp., and Indigofera sp. (For more complete lists see Blake (1938), Davidson (1954), Allen and Roe (1943))

The pasture derives its value to a considerable degree from the annual components. The acceptability of Mitchell grass is such that it is not selectively grazed and upon drying it does not become brittle and break up to the same degree as annual grasses such as Iseilema (White, 1934) so that in this state it is acceptable to stock. Thus, it is able to carry stock long after other plants have been eaten off or in times when development of the other pasture components has been affected by drought.

Development of a Mitchell grass pasture takes place in two distinct phases. Summer rainfall promotes growth of gramineous spp. and some perennial herbs. Winter rain promotes growth of winter annuals which, if present, despite their lack of bulk, increase the protein content of the pasture.

b) Taxonomy and Characteristics of Mitchell Grass

(i) Species of Astrebla

Four species of Astrebla have been recognised.

A. lappacea	"curly"
A. elymoides	"hoop"
A. squarrosa	"bull"
A. pectinata	"barley"

Jozwik (1969) states that A. lappacea is the dominant species in central and north-central Queensland. In southern Queensland it is sometimes locally dominant, but more often occurs with A. pectinata and other perennial grasses. A. squarrosa seldom assumes dominance and is usually a minor element in communities dominated by A. lappacea or A. pectinata. A. elymoides occurs concurrently with and occupies essentially the same niche as does A. squarrosa. A. pectinata, while dominant in the Northern Territory, may become locally dominant in Queensland, but is less abundant than A. lappacea.

The local distribution of the four species of Astrebla appears to be dependent on soil moisture. Weston (1963) holds that A. squarrosa occurs in low areas receiving run-on water, while A. lappacea occurs on well drained downs, and A. elymoides occurs as a transitional community between the two. Weston maintains that the habitat of A. pectinata is uncertain, but it may be confined to soils with less tendency to crack severely.

Strong evidence exists for the existence of hybrids of all four species. However, Jozwik (1969) has shown by bagging at flowering time that the genus is self fertilizing, although hybrids do occur.

(ii) Morphology

Mitchell grass is a perennial summer-growing tussock-forming grass. Individual tussocks vary considerably in size, but often exceed a diameter of one foot, at which size they may have over a hundred culms.

The persistence of Mitchell grass is largely dependent upon its root stock. The root stock branches freely and the direction and extent of its growth determine the shape at ground level of the tufts. Sheathing scales envelop the hardened tissues of the root stock.

The root stock gives rise to large numbers of robust roots which by penetrating first outwards and then vertically downwards are able to draw upon the last reserves of soil moisture. Root penetration terminates at four feet. For the first two feet the roots are strong and hard and apparently have a similar texture to that of the root stock. Below two feet, decrease in size and hardness becomes apparent. At the depth where the soil cracks end, the roots branch again into fine rootlets and the main bulk of feeding roots is developed in and below this layer. After rain the roots near the surface produce very fine rootlets which persist as long as the surface soils remain moist (Everist 1964).

The Mitchell grass plant produces two main kinds of tillers. Main tillers arise from scaly buds on the root stock. From the axils of old main tillers, axillary tillers may be developed. The growth of each of these is determined largely by rainfall. The leaves are firm in texture and lack succulence when mature, a feature which contributes to their durability (Everist 1964).

(iii) Germination and Establishment

Fresh Mitchell grass seeds germinate poorly (26% one week after harvest), but germination increases to 88% after twelve months (Myers 1942). Germination occurs over the range $15-42^{\circ}C$, but little occurs below $22^{\circ}C$ and above $35^{\circ}C$ (Jozwik *et al* 1970). Seeds are enclosed in a tough seed envelope such that a good fall of summer rain is necessary for germination. The primary roots are thin and brittle and seedlings are thus easily destroyed by grazing. Everist (personal communication) maintains that two rains are needed for establishment, the second some six weeks after the germinating rain, so that tillers and adventitious roots are able to develop.

(iv) Growth and Development

Whilst soil moisture is the major limiting factor in the growth and development of the Mitchell grass plant, winter temperatures are sufficient to suppress growth and in some cases bring about cessation of growth.

Jozwik (1970) has demonstrated that the optimum temperature for tillering is 23-28^{o}C while growth per tiller and leaf production increased with temperature up to 25-30^{o}C. The inherent tillering capacity of Astrebla appears to be related to the microhabitat which each species frequents. Jozwik records A. elymoides and A. squarrosa as occupying niches with higher soil moisture than A. pectinata and A. lappacea. He concludes that those species not subjected to moisture stress as soon after rain as plants on higher ground would not need to develop as quickly and this may account for the lower tillering ability of A. squarrosa and A. elymoides.

Mitchell grass exhibits two separate responses to rain depending on the amount of rain that falls. Following rain, A. pectinata plants respond by producing new axillary tillers from the lower nodes of the old main tillers, mainly the three lowest distinct nodes. These new axillary tillers grow readily and flowering occurs about thirty days after rain commences. When rainfall exceeds 50 mm, in addition to new axillary tillers, new main tillers are produced. These new main tillers arise from basal nodes of old main tillers or from rhizomes or both (Jozwik et al 1970).

From an examination of starch reserves within various parts of the plant, Everist (1964) concludes that new axillary tillers are produced from starch stored in the stems, while starch stored in the rhizomes and roots is used in the production of new main tillers. In this way root reserves of starch are not utilized to any great extent unless good rains have fallen.

Photosynthetic activity during the growing period replenishes the carbohydrate reserves of the tussocks. In a pot trial, forty days after growth commenced, rapid internode elongation and broadening of the leaf blades occurred and this was associated with a rapid build up of soluble sugars. Between forty and eighty days after growth commenced the ratio of total soluble sugars to starch fell rapidly indicating rapid translocation of soluble sugars (Haydon 1970). Although the growing period under natural conditions does not usually occur over as great a period, a similar pattern of starch build-up would be expected to occur under field conditions.

The growth period of Mitchell grass is variable, but from four to six weeks is common. Seven weeks after 937 points fell in summer at "Gilruth Plains" seed heads were beginning to dry and basal leaves had dried and curled (Roe 1941). Roe also reported that the drying of seed heads of A. lappacea and A. pectinata was more rapid than that of A. elymoides. This is consistent with Jozwik's conclusion that because A. elymoides and A. squarrosa occupy situations of more favourable soil moisture, early maturity is not necessary for survival as in A. lappacea and A. pectinata.

(v) Dry Matter Production and Botanical Composition

It has already been emphasized that precipitation shows the highest correlation with growth and that development of a Mitchell grass pasture depends on the seasonal distribution of rainfall.

The dry matter yields of different Mitchell grass pastures at various sites after varying rainfall are presented in Table 1. The effect of low rainfall can be seen in the results from "Brunette Downs" and "Amburla".

Table 1. Dry matter yields of Mitchell grass pastures at different sites.

Yield (kg/ha)	Rainfall (mm)	Growing Season ₮	Site	Source
250-400	105 163	Jan - March Jan - March	Amburla, N.T. Brunette Downs, N.T.	Jozwik et al 1970 Jozwik et al 1970
2250+	400+	Oct - April	Elderslie, Winton	Davies et al 1938
1750*+	430+	Oct - April	Gilruth Plains, Cunnamulla	Roe and Allen 1945

* Represents maximum presentation forage yield in a grazing trial at 1 sheep to 5 acres under continuous stocking.

₮ Represents growing season as determined by rainfall.

\+ Approximate.

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When medium to heavy summer rain falls, the total amount of forage produced reaches a peak in late summer. From this late summer peak, yields decline slowly as various constituents of the pasture attain maturity and shed seeds and leaves, while the perennial species transfer food reserves under ground Davies et al 1938).

Winter rains induce responses mainly from non-graminaceous species and, from the yield data available, appear to exert little influence, if any, on dry matter production of total pasture.

Concerning botanical composition, Griffiths Davies et al (1938) have recorded the relative contributions of various components of a grazed Mitchell grass pasture at Winton at a number of stages following good summer rain.
These data are summarised in Table 2.

Table 2. Relative contributions of components of a grazed Mitchell grass pasture to yield (Griffiths Davies et al, 1938)

Sample Date	Rainfall (points)	Total Yield cwt./ac.	Botanical Constituents (%)		
			Perennial Grasses	Annual Grasses	Miscellaneous Herbs
22.10.35	75	1.30	33.59	2.67	63.74
19.11.35	96	0.90	49.58	0.84	49.58
17.12.35	33	0.69	42.99	1.41	55.60
21.1. 36	368	0.27	92.59	-	7.41
18.2. 36	213	1.89	71.16	5.03	23.81
10.3. 36	476	10.20	48.38	27.28	24.34
8.4. 36	404	17.99	67.20	23.36	9.44
6.5. 36	40	16.71	63.98	30.21	5.81
2.6. 36	233	15.16	70.13	19.54	10.33
30.6. 36	-	16.82	79.36	12.76	7.88
30.7. 36	26	15.56	71.69	24.36	3.95
25.8. 36	15	13.83	74.00	22.31	3.69
23.9. 36	-	14.51	79.95	18.40	1.65

One notable feature is the 92% contribution to yield of perennial grasses, mainly Mitchell grass, soon after rainfall commences and how this declines as the summer growing season progresses. This is brought about by the increase of annual grasses, whose early contribution is low because they have to start as new seedlings. As these annual grasses are selectively grazed, the contribution of Mitchell grass again increases. The response of the miscellaneous herbs group to both summer and winter rain is apparent.

The relative contribution of Mitchell grass to pasture yield varies considerably. Good summer rain following a drought at "Gilruth Plains" produced a pasture of which Mitchell grass contributed only 7.9% of the total yield and this contribution came almost entirely from mature plants (Roe 1941). Thus, in considering the productivity of Mitchell grass pastures, past seasonal conditions and grazing practices can have an important bearing on current productivity.

(vi) Nutritive Value

Unlike other highly valued grasses, Mitchell grass does not derive its value from its nutritive properties, but rather from the fact that it is a feed source when all other grazing plants have disappeared. Weston and Moir (1969) have described the sequence of selection by merino ewes of single species, grazing a Mitchell grass pasture in north-western Queensland. The selectively grazed plants such as Boerhavia diffusa and Dactyloctenium radulans have crude protein contents of 19.1% and 14.5% respectively. Although some shoots of Astrebla pectinata were grazed, the herbs, forbs and annual grasses were preferred. As other feed became scarce, they found that the sheep selectively grazed different parts of the different species of Mitchell grass. Chemical analysis showed that those parts grazed selectively had higher crude protein contents than whole plant samples.

The seasonal pattern of nutritive value of Mitchell grass as described by Weston and Moir emphasises the variation in pasture quality offered throughout the year. Towards the end of the year when sheep are in negative nitrogen balance, leaves and pods of the leguminous Acacia farnesiana are selected.

Progressive deterioration of both quality and quantity generally occurs after April and is continued until new growth takes place (Davies et al 1938). In the northern Mitchell grass areas, e.g. Longreach area, this new growth does not normally occur until the following summer. In the southern Mitchell grass areas, e.g. Cunnamulla, winter rain produces

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growth of small annual herbs ("herbage") which improves pasture quality. However, this winter rain also causes "blackening off" of standing Mitchell grass hay, such that further deterioration occurs.

3. Successional Patterns

Whereas vegetation changes are progressive in most countries, as mentioned earlier, evidence points to the fact that the vegetation of western Queensland is oscillating. Blake's (1938) "fluctuating climax" denotes a condition which appears relatively stable but which in reality is in a state of unstable equilibrium.

Everist (personal communication) described the climax as "opportunistic" as it is the result of rainfall and its distribution at any particular time, and to a lesser extent, to the effect of the grazing animal. A similar view is expressed by Allen and Roe (1943).

Holland and Moore (1962) conclude "It is therefore possible that the present dominance of Astrebla spp. in these grasslands has been brought about by the grazing animal, and that the original dominant under natural conditions may have been Dichanthium sericeum". Closer observation in the Leichhardt and Maranoa districts, where Astrebla spp. are reported to increase following dry years, may provide valuable information regarding the successional relationship between Astrebla spp. and Dichanthium sericeum.

The relative effects of rainfall and grazing on succession and retrogression have yet to be elucidated. For the Longreach district, however, an attempt to describe stages of retrogression on heavily grazed areas, e.g. around watering places, has been attempted by Davidson (1954) and can be represented as follows:

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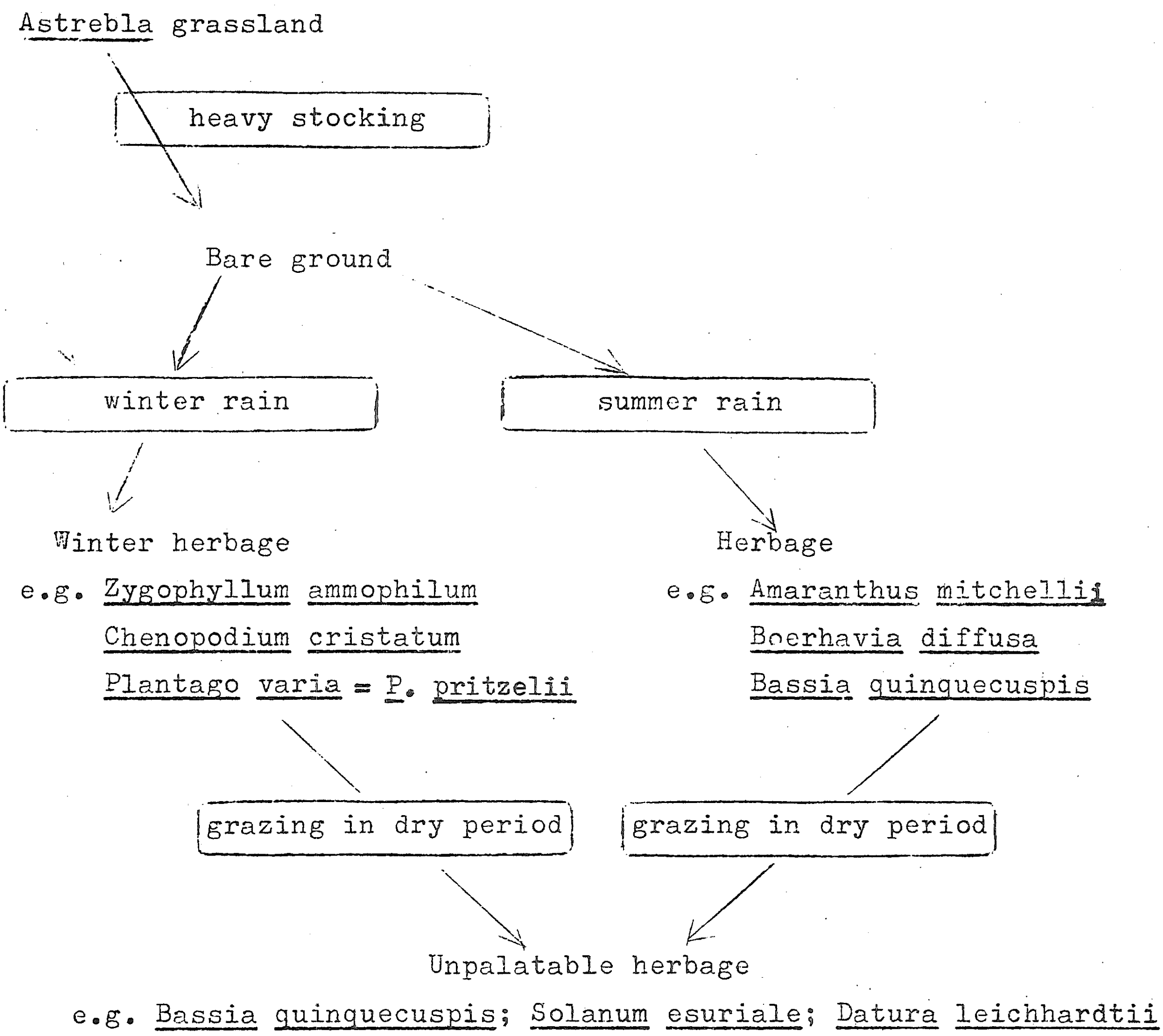
Diagram 1. Attempted representation of successional pattern following heavy stocking for the Longreach district (after Davidson, 1954).



With exclusion of stock for eighteen months, competition from Cenchrus ciliaris has greatly reduced the Salsola kali population. A similar succession may well be obtained on cracking clay Mitchell grass soil. Apart from the effects of rainfall and grazing on botanical composition, Blake (1938) suggests the possibility of cyclic variation in salt content of the soil as an important factor in vegetation succession.

In the Cunnamulla area, Allen and Roe (1943) report that Dactyloctenium radulans increases after Astrebla spp. have been reduced by very heavy grazing. Following a decline in perennials there is a general appearance of herbs such as Abutilon malvifolium and Hibiscus trionum which these authors conclude are indicative of a deteriorating pasture.

Information on local successional patterns is scarce. Further work to elucidate the floristic detail, particularly in relation to the differential effects of the grazing animal and rain, both separately and together, should be collected. Because changes towards a better type of pasture are extremely slow, while changes to a poorer type of pasture are rapid, this floristic detail would enable early stages of pasture deterioration to be recognised.

C. DETERIORATION OF SEMI-ARID PASTURES IN AUSTRALIA - EVIDENCE, SYMPTOMS, CAUSES.

1. Western Queensland

The question of establishing the degree of deterioration of the grazing lands of western Queensland is difficult to answer in quantitative terms. While many shades of opinion have been voiced on this issue, the shortage of ecological benchmarks, in the form of protected areas, accurate descriptions, photographic evidence and survey data, makes verification of individual memory judgements very difficult. Under the circumstances, it may be more meaningful to evaluate the significance of certain attributes of present vegetation and soil surface and then to postulate on the meaning and possible causes of such symptoms.

During 1971 a set of questions was circulated to Agrostologists with experience of the pasture situation in western Queensland. These questions and the suggested sources of information required to answer them were drawn up by the writer in an attempt to pool enlightened opinion on the present state and potential of the region concerned.

Concerning evidence and causes of deterioration in the mulga lands of this area, respondents were all of the opinion that deleterious changes had taken place in western Queensland since settled stock farming began. The forms of change enumerated by respondents were:

(a) sparser vegetation
(b) increase in woody plants
(c) increase in annual "herbage"
(d) decrease in perennial grasses
(e) exposure of scalded clay surfaces
(f) silting up of waterholes.

The reasons put forward by the Agrostologists for these changes were:

(a) non-prolific regeneration of preferred species
(b) withholding of fires
(c) drought feeding for sheep since late 19th century.

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During the period of this study, the writer has had ample opportunity of soliciting the opinion of many experienced landholders in western Queensland. While a number of viewpoints stress the economic reasons for the grazing pressure which has been imposed upon the natural pastures of this area, the majority of informed opinion considers continuous sheep grazing as the most important factor leading to a decrease in the perennial grass population.

In response to numerous requests for assistance with soil conservation problems in the mulga zone of south western Queensland, an investigation was undertaken (Skinner and Kelsey, 1964) to determine the form and distribution of erosion in the areas, as well as to establish the causes and effects of such erosion. Although this investigation did not fully attain the above objects, the report did conclude that, "The evidence strongly suggests that a gradual but serious deterioration of this land has occurred, especially during the past 20 to 30 years, and that this decline is continuing". Photographic evidence of spectacular soil loss from the base of dated fence lines points to the need for improvement of vegetative cover by ecological means, rather than mechanical banking and waterspreading which was the main recommendation of the report.

Whitehouse (1941) reports that, "Over most of western Queensland it is evident that springs are declining; that waterholes are silting; and that supplies (of water) consequently are less lasting". These retrogressive symptoms are put down to three main causes: (a) General decline since Pleistocene times (Carnarvon station, at the head of the Nogoa and Warrego rivers, was entirely watered by natural waters when first settled. Today no permanent waterhole exists there).
(b) Overall decline of water supplies over the two decades preceding 1940, due to below average rainfall. (c) Through a decline of vegetation, runoff is more rapid and the rate of erosion and thus of the volume of transported silt is greater than formerly (Whitehouse, 1941). Of the three factors causing depressed water supplies, only one is subject to partial arrest by Man. Ebersohn (1967) has compared the opinions of several authorities on the degradation of the vegetation of western Queensland (Blake, 1938; Everist, pers. comm. and Davidson, 1954). Blake's (1936) early warning of retrogression

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of the natural pastures of Queensland deserves serious evaluation: "The grazing lands of Queensland are one of the State's greatest assets, and on their condition depends to a great extent the prosperity of this country. In many districts, unfortunately, these lands have deteriorated very considerably. The deterioration is brought about either by the more or less complete disappearance of edible plants or by the replacement of palatable species by less palatable species." Blake (1936) describes the part played by various Bassia species in this process, particularly where they occur in the Mitchell grass area and adds, "It is commonly stated that over-stocking is chiefly responsible for pasture deterioration, and in a sense this is completely true". He makes the point that in times of severe drought "almost any stocking is over-stocking" and mentions insufficient opportunity for natural seeding as a factor militating against good recovery of pastures. Fenced off strips which could act as a seed source were suggested by Blake to counteract this factor.

In attempting to establish whether overgrazing has taken place, Ebersohn (1970) writes, "It should be not too difficult to recognize overgrazing from plant, soil, creek and waterhole indicators. Among others, do the densities of plants of low use remain static? Do plants invade from outside? Is there damage to tree reproduction? Are creek or waterway breakaways forming? Are waterholes silting up?" Unfortunately very little documented evidence is available on these important questions.

The Mitchell grass country of western Queensland has become known for its relative stability and resistance to grazing. Nevertheless, evidence of detrimental changes has been documented and such changes have been attributed to rainfall and stocking.

Rainfall

The great variation in annual rainfall at any particular site over a number of years has already been mentioned. Deterioration caused by depleted soil moisture is manifest in the size and number of individual perennial tufts, and Winders (1936) reports that the centres of Mitchell grass tufts die out prematurely under such conditions.

Following a year in which severe drought caused the pasture at "Gilruth Plains" to be in a very poor state, good summer rain in the subsequent year produced a dry matter yield of which Mitchell grass contributed only 7.9%. Rainfall on the area had been low and was the cause to which the poor contribution of Mitchell grass was attributed. The adverse season was reflected in the low number of young plants following rain and by the number of mature plants which failed to respond to the rain (Roe 1941).

An examination of ten year periods of rainfall by Francis (1935) shows a somewhat cyclic pattern of rainfall with several years of above average rainfall followed by a period of below average rainfall which is capable of adversely affecting Mitchell grass in common with other vegetation.

Grazing

The literature reveals that there are a number of ways by which grazing can cause deterioration of Mitchell grass. These are:

a) By the grazing of Mitchell grass seed (Weston and Moir 1969).

b) Removal of seedlings by the grazing animal before the secondary root system becomes functional (Everist, personal communication).

c) Excessive grazing during active growth such that carbohydrate accumulation in the root stocks is prevented (Roe and Allen 1945; Everist, personal communication).

d) Grazing below 15 - 20 cm during the plants' dormant period (Jozwik 1970).

e) Burrowing for roots by sheep when the ground above soil level is apparently devoid of forage (Roe and Allen 1945; Hirschfeld and Hirschfeld 1936).

Diet selection studies in north western Queensland by Weston and Moir (1969) show that sheep are capable of causing deterioration of Mitchell grass by all of these means. Unless heavily overstocked, however, it is difficult to see that a) or c) could be great contributors to deterioration as Weston and Moir showed that grazing of seedheads and of the actively growing plant was not extensive.

The effect of cattle on Mitchell grass is as yet not clear. In view of the large scale increase in cattle in the Mitchell grass country, this is one question most in need of an immediate answer. Further information on dietary habits of the kangaroo is also necessary.

By selective grazing of seedheads when available, Everist (personal communication) believes that horses are capable of causing deterioration of Mitchell grass.

While it has been convenient to discuss the effects of rainfall and of grazing on deterioration separately it is in practice very difficult to distinguish between the two. Roe and Allen (1945) report that where reduction of Mitchell grass could be measured, it is difficult to determine whether the cause is due to seasonal or grazing effects.

The experimentally ideal situation whereby stocking rate is varied on a seasonal basis is totally unacceptable to pastoralists for economic reasons. The situation often arises, therefore, that the stocking rate maintained at the beginning of a below average season constitutes potential overgrazing, if at least a partial destocking policy is not adopted. In such a situation pasture deterioration may well be expected to occur. In this situation it is impossible to attribute such deterioration to either reduced rainfall or to overgrazing.

Deterioration of Mitchell grass pastures either by lack of rainfall, overgrazing or by a combination is a cumulative process. This cumulative deterioration occurs as a result of continual interference with the normal physiological processes of the plant, which in turn impairs vigour. (Continued overgrazing results in a breakdown of the stand and death of individual plants.)

In addition to the abovementioned type of overgrazing, the chance of causing deterioration has been greatly increased by the advent of nitrogen supplementation. This encourages the grazing animal to utilize plant stem that may not have been accepted without supplementation and a great danger to the stability of the Mitchell grass country is posed by this technology.

Because of the gradual drop in productivity, it is difficult to recognise the early stages of pasture depletion. The first signs are reflected in the growth of the better elements and as the stand of desirable plants is opened up, the annual and short-lived perennial weeds appear, develop and reproduce. While it is not always possible to recognise the

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initial stages of weakening of Mitchell grass, a knowledge of the weeds indicative of early deterioration would enable pastoralists to take timely action to halt further deterioration. For this purpose it is necessary that indicator plants be determined and listed.

While overgrazing may lead to deterioration of Mitchell grass pastures, Winders (1936) concludes that under-utilization may also be deleterious to the vegetation, although not to the same extent as overgrazing.(Underutilization is evidenced in the "Gilruth Plains" exclosure, see survey sites no. 23 and 24 in Appendix A).

Although most pastoralists maintain that Mitchell grass is "indestructible", it is apparent that while it is very resistant, elimination of Mitchell grass is possible. Winders (1936) reports that "something less than full use of the forage is necessary to maintain the pasture in good condition under continuous grazing". For this reason injudicious grazing combined with prolonged drought constitutes a real threat to the stability of the Mitchell grass grasslands.

2. Other States:

In view of the dearth of factual evidence on the deterioration position in western Queensland it could be fruitful to examine the evidence available from other semi-arid and arid Australian regions. The regions concerned have been subject to continuous sheep grazing for a similar period, are dominated by the same genera of plants as occur in western Queensland, and in most cases they have similar soils. Four main vegetation types (Mulga, Saltbush, Mitchell grass and Spinifex) make up the greater part of semi-arid and arid Australia and evidence on deterioration is quoted below from these types, Mulga and Mitchell grass being particularly pertinent to the western Queensland situation.

This compilation of extracts from Australian work on the condition of semi-arid pastures is not intended as yet another literature review of existing knowledge and opinion. The Broken Hill Arid Zone Conference (Anon, 1970) has given a comprehensive overview of the situation in arid Australia.

The extracts,which follow, have been selected and arranged only to ascertain, on the strength of the evidence, the need for more realistic research, legislation, administration and land use practice in Australia's semi-arid interior. Despite what is claimed for the stability and satisfactory condition of the pastoral areas by some workers, the evidence quoted here may expose a dangerous situation which could warrant a higher priority amongst present national problems. No apology is made either for the repetition of similar statements or for the generous use of verbatim extracts, both of which are aimed at stressing accurately the opinions of many authorities.

The apparently serious threat that vegetation deterioration may pose in Australia's drier regions has been identified and acted upon to a greater extent in New South Wales than elsewhere. Early recognition of the position led to the investigation by the Royal Commission (1901) which, in a comprehensive evaluation of the situation, listed among the causes of pasture deterioration, an ill-advised land tenure system and gross overestimation of the carrying capacity of the western division. More recently the need for a positive ecological approach to this problem has been enunciated by Moore (1969) who, while primarily concerned with shrublands, stresses that "investigations are equally necessary in the Astrebla grasslands if productivity is to be maintained". The various deleterious influences which settlement imposed on the pastures of New South Wales have been fully enumerated by Anderson (1941), following on the earlier warnings of the future possible dangers of over-utilization sounded by Osborn (1928).

The decimation of the stock populations of semi-arid areas, together with great changes in vegetation, during times of serious drought, were inevitable in Beadle's (1960) view, because of the lack of knowledge on vital ecological controls: ".....Carrying capacity, rainfall, techniques of grazing and rates of regeneration were unknown". The general trend in the dry areas has been firstly a decrease in density of less palatable species, and finally the dominance of **useless weeds** (Beadle, 1960). Recent research by Marshall (1970) has attempted to quantify the protective role of shrubs against wind erosion, as related to shrub density. The writer has shown how stepwise improvement or deterioration of natural grazing lands depends primarily on the regulatory effect of plant cover on soil, moisture and fodder production (Roberts, 1971).

A common retrogression situation is described by Moore (1969) for deteriorating grazinglands in Australia: "Range deterioration, with depletion of the cover of the herbaceous species, essentially the perennial grasses, is quickly followed by extensive soil erosion. Wind erosion during droughts and sheet erosion on the bare surfaces during heavy summer thunderstorms have left many areas denuded of the original topsoil. This has resulted in nutrient losses and effects on secondary succession, but probably more important has been the change in soil moisture relations. Surface run-off is extensive on the hard and compact exposed subsurface and little of the rain falling on an area of even gentle slope penetrates the soil. The environment therefore tends to be more arid, and germination and establishment of herbaceous species is to a large degree inhibited. In the simplest terms, the vegetation as it exists today is less productive (in terms of animal products) than the original vegetation, and degeneration is still proceeding. If a stable pastoral industry is to be maintained, the process must be arrested and reversed".

Beadle (1948) made one of the first extensive studies of pasture deterioration in Australia and his observations in western New South Wales can in all probability be applied to many other semi-arid areas, including western Queensland: "Since the sheep is a selective grazer, plants disappear in most cases in order of their palatability. Furthermore, perennials for the most part do not regenerate as rapidly as annuals and consequently palatable perennials disappear before palatable annuals. Thus in any overgrazed pasture, vast floristic changes appear in the sward, and from a study of the botanical composition of these degenerate pastures it is possible to compile a list of plant species which can be used as indicators of degeneration, and possibly of erosion". Beadle lists the following such indicators:

(i) Bassia. Almost every species but, in particular, B.birchii, B.quinquecuspis, B.divaricata, B.tricuspis and B. longicuspis.

(ii) Nitraria schoberi

(iii) Kochia microphylla

(iv) Carthamus lanatus

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(v) Native annuals, notably composites such as *Helipterum* spp., *Calocephalus* and *Craspedia*.

(vi) Members of the Cruciferae, e.g. species of *Hutchinsia* and *Lepidium*.

The important effect which overgrazing in certain semi-arid areas is having on erosion and nutrient loss is shown with quantitative data by Charley and Cowling (1968), who also maintain that this loss limits secondary succession. Soil erosion is seen by Moore (1959) as the main factor responsible for the slow recovery of overgrazed areas, following exclusion of stock. The examples recorded by Booth (1941) in Kansas and Costello (1944) in Colorado, took 51 years and an estimated 35 years respectively for the former perennial grasses to return.

In South Australia, as in New South Wales, retrogression of the vegetation and of the saltbush in particular has been evident for many years. One of the earliest records of pasture deterioration in the semi-arid areas is that of Dixon (1892) who, in referring to the north western districts of South Australia,wrote "...The injury to the original vegetation by overstocking has assumed so great a magnitude as to entail a national loss". In his examination of the erosion problems of parts of semi-arid Australia, Ratcliffe (1937) did not find extensive erosion in far south western Queensland as in the case of arid South Australia. However, he made one unqualified statement on the drier pastoral regions as a group: "Whenever and wherever pastoral settlement is imposed on semi-desert areas with a variable and uncertain rainfall, the problem of the survival of certain components of the vegetation is automatically raised". It is indeed tragic that the species which are usually threatened are the drought-resistant perennials on which stock depend when annuals fail.

Despite the hardy nature of the saltbush vegetation of arid South Australia, as early as 1936 it was estimated that even at that time, only 10 to 25 percent of the original bush cover remained (Ratcliffe, 1936). According to Woodroffe (1941), "It is now widely recognized that mismanagement, chiefly overgrazing by sheep, is to blame for the widespread depletion of a limited resource of plant capital." Moore

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(1960) also gives a detailed description of the effect that sheep have had on the Australian vegetation, emphasizing the increase in useless plants at the expense of the original perennial fodder plants. Osborn, Wood and Paltridge (1932), in one of the earliest grazing investigations on arid pastures in Australia, amply demonstrated that saltbush (Atriplex sedifolia) "benefited from moderately heavy grazing and that intermittent heavy grazing improved both the vigour of the bush and the establishment of its seedlings.

Referring to the semi-arid areas of South Australia, Ratcliffe (1937) maintains that the system of stocking practiced there, "must inevitably result in the progressive reduction of the slow-growing, ever-green fodder plants".

While many authorities have made qualified statements on the possibilities of the existence of pasture deterioration, and its causes in the drier regions, Perry (1968) states unambiguously, "The advent of sheep and cattle grazing to Australia's rangelands initiated a downward trend in range condition". He adds, however, that due to the short grazing history and inherent stability of the ancient land surface of these rangelands, "at present most of the ranges are in fair to good condition". Some areas, particularly those with either a relatively long grazing history or where the landscape is more recent, are admittedly in "poor or very poor condition". This assessment probably applies to the spinifex country where permanent water is very scarce, but it may not be true of those areas of the Great Artesian Basin of Queensland which have been well watered since the first bore (Blackall, No.1) was sunk in 1885 (Anon. 1954). Perry (1970) also attributes this relatively good condition partially to the fact that perennial species are less palatable than shorter-lived plants and they therefore get natural deferment after good rains. It may be necessary to establish the validity of this last named generality.

The degree and extent of deterioration have unfortunately not been documented for most of the arid area of Australia, but it has been inferred from stock numbers (Heathcote 1964, Moore 1969, Royal Commission 1901, Ratcliffe 1938) that degradation of pastoral Australia, in terms of carrying capacity, has been widespread. In the absence of evidence on possible change in rainfall, the deduction is made that this retrogressive process is due primarily to stocking. Perry (1968) presents the graphed data on cattle and sheep numbers in four States between 1860 and 1960 to illustrate this important fact. Newman (1971) has recently summarised the historic stock number fluctuations in five States, re-emphasizing the present depressed productivity of virtually all Australia's rangelands.

Apart from depressed animal numbers, many writers have recorded the associated reasons for the impact which domestic animals have had on the plant communities of semi-arid Australia. Basically the increased grazing pressure has only been possible as a result of the provision of much more well distributed permanent water supplies than was the case under natural conditions. Water development has simultaneously led to an increase in the sedentary marsupial population. Griffiths Davies (1955) maintains that overstocking by sheep was particularly severe in the forty year period ending 1920, "before the full knowledge of the delicate balance of the vegetation with the harsh environment was realized". As referred to earlier, the most searching investigation of evidence on pasture deterioration in semi-arid Australia, was the Royal Commission (1901) which examined the situation in western New South Wales. This comprehensive evaluation of the situation named five causes of pasture degeneration: drought, rabbits, destruction of vegetation during droughts, the spread of inedible woody plants, and overstocking.

The low carrying capacity of the natural grazing lands of the drier regions eliminates the use of costly methods of manipulation of woody weeds and emphasizes the need for the application of ecological principles in management. To do this, it is necessary to identify the causes of deterioration and to understand the retrogressive processes involved. Moore (1969) states quite clearly that, "The single basic cause of change has been the direct and indirect effect of the activities of white man since settlement". Apart from overgrazing, the change in fire pattern and fire effectiveness must be regarded as one of the major causes of vegetation deterioration and, in particular, the increase in woody species.

In analysing the selective development of present-day natural pastures, Williams (1968a) writes, "The present pastures are generally made up of plants which have accommodated themselves to past grazing pressures and drought so successfully that they are difficult to remove by normal management". He maintains (Williams 1968b) that in certain regions long-term deferment procedure is unlikely to be of much value in reclaiming degraded pasture because most of the species that needed periodic deferments are no longer present. The opinion is held (Williams 1968a) that certain substantial changes in the "basic composition of the pastures" are permanent and that "further drastic shifts can be anticipated, possibly from sparse perennial grasses to scrubland or to ephemeral grassland". The general trend has been towards "an increase in species which do not grow in dry periods and a decrease in acceptable species which do" (Williams 1968a).

In the case of kangaroo grass (Themeda australis), it is difficult to equate the opinion that this grass is relatively unpalatable with the fact that this species is today virtually limited to railway enclosures (Whalley,1968) and that White (1934) should record, "Some of the best pastures (in Queensland) are composed of Kangaroo Grass in almost a pure stand". Moore (1960) has noted that Kangaroo grass "is more persistent in cattle country".

In most parts of the pastoral zone there are apparently serious problems arising out of the need to preserve communities of useful species and to prevent encroachment by species that are either toxic or useless for grazing. This is prone to occur whenever a sere is created either by over-grazing, drought, or by mechanical means, or when soil moisture relations are altered by water-spreading, drainage, etc. In Western Australia, South Australia, western New South Wales and Queensland extensive degraded areas require reclamation. In central Australia Chippendale (1963, 1965) has documented the process of pasture deterioration, indicating how disappearance of palatable perennials has led to replacement by inedible perennials and hardy annuals. In Australia's contribution to a world survey of browse fodder, Roe (1947) indicates the dangers of overuse of topfeed, which could lead to the serious situation which has developed in the many other semi-arid countries documented in the same survey.

Australia is in the enviable position of being able to learn from the mistakes made by other countries in the field of deterioration of natural pastures as pointed out by Box and Perry (1971). The question is, will Australia profit from the lessons of history, or will she, as so many other nations have done, ignore the writing on the wall until Nature leaves her no option but to make the necessary changes in resource use? It behoves Australian universities to act on Box's (1969) training recommendations.

This review does not include a detailed examination of the economic and political aspects of the deterioration of grazing lands, however, a few points need to be raised here. The effects of economic pressure on the treatment of semi-arid grazing lands have been reiterated by Perry (1970): "During periods of low profitability, graziers tend to offset the low return per animal by increasing their flocks and herds - as Barnard (1969 p. 219) said,'they are driven to make the soil pay' and pay it literally does. The resultant overgrazing and range degeneration can reduce the productivity of the land for all time". The general negative processes currently taking place in arid pastoral areas are referred to by Perry (1969) as follows: "The rangeland pastoral industries are valuable but, because of the lack of knowledge, they are exploitative, i.e., they are mining the land resources on which they depend. Continued and accelerating deterioration can be expected unless scientifically based management practices designed to preserve the rangeland resources are adopted". Although Heathcote (1968) maintains that, relative to other primary producing areas, pastoral land seems to provide a greater return on capital, he does not indicate what the effect of past practices have been on "land capital". Although perhaps not directly related to deterioration, it is worth noting that approximately half of the properties in the wool-growing region of pastoral Queensland had credit or debt not exceeding 10% of the property market value, but one property in five was estimated to have debts exceeding 60% of their market value in 1970 (Bain and Waring, 1971).

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PART II. INVESTIGATION INTO THE LOCAL APPLICATION OF PASTURE CONDITION ASSESSMENT

A. INTRODUCTION TO CONDITION AND TREND ASSESSMENT

1. Definition of concepts

(a) Range condition: Range condition may be described as the general state of health of natural grazing land and was originally defined as follows: "The state of health or productivity of both soil and forage of a given range, in terms of what it could or should be under normal climate and best practicable management" (Glossary of technical terms, Society of American Foresters, 1944). The term has been generally used to refer to "the response of forage cover and soil to the grazing practice in operation, taking into account also current climatic conditions". In broad terms, condition depicts, for specific range units, "the character, amount and stability of the forage crop and the amount and quality of livestock products that each should produce" (Sampson, 1952).

Because conditions may be changing, a report of condition is always with reference to a certain time and as Dyksterhuis (1960) has pointed out, data on condition are gathered "to show current condition in relation to potential condition, thus enabling a range manager to recognize an attainable goal". "Range" and "rangeland" are terms usually applied only to those areas which have climatic and edaphic conditions which lead to a climax vegetation suitable for natural pasture. The term climax in turn is widely used by range research workers to indicate a "stable" vegetation where plant succession has reached its environmental limit. In Australia the term "rangeland" is used in general terms to designate the arid and semi-arid areas unsuitable for crop production (Box and Perry, 1971).

One of the simplest definitions of condition is that of Ellison (1951) which states that "condition is the character of the vegetal cover and the soil, under man's use, in relation to what it ought to be". Over the years, the term "condition" has come to mean two different things depending on the object of condition assessment. Thus in basic ecological terms, condition refers to the ecological state of health of the grazing land, while in short term stocking rate judgements it refers to the amount of feed available.

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The first proposed range condition assessment was that of Smith (1899) who suggested that "the occurrence of any one species as a dominant or most conspicuous grass is, to some extent, an index of the state of the land and of what stage in overstocking and deterioration has been reached". In the American context, range condition classes are essentially "successional stages of plant communities as influenced by grazing use" (Parker, 1954).

Grazed rangeland in its most healthy state is natural grazing land which has been used by grazing animals "on a sustained yield basis and which is in an optimum state of soil stability and quality, and of vegetational development" according to Parker (1954). Thus relative to this ideal state, grazing land may be classed as excellent, good, fair or poor. For each type of grazing land, standards are drawn up for cover, botanical composition, vigour and soil condition in each class of condition.

(b) Trend: The term "range trend" refers to the direction of change in condition of natural grazing land. In its original context, "trend" indicated whether "the state of health, and thus productivity of rangeland, was moving toward or away from the climax condition. It is generally accepted that most types of vegetation are dynamic in the sense that they will change in botanical composition and cover (density) in response to both climatic and management changes. For this reason range condition is seldom constant and although changes may be slow and inconspicuous, particularly in dry regions, changes in the direction of recovery (progressive) or deterioration (retrogression) can be identified and are known as "range trend". In its simplest terms "trend" is change in condition.

Both the direction and the rate of change in range condition are embraced by the concept of "trend" and are influenced by a complex of environmental and management factors.

(c) Key species: The use of the "key species" concept was first proposed by Standing (Anon, 1938) as a basis on which correct utilization of grazing land could be judged. The key species are those species on which the correct level of defoliation for the vegetation as a whole is judged. Key species should be palatable, reasonably resistant to grazing and competition, reasonably abundant and nutritious and should produce a reasonable volume of feed.

Provided key species have been correctly identified, the amount of forage per unit area increases as the proportion of key species in the community increases. Overgrazing of the range is indicated by too intensive defoliation of one or more key species. In addition, the vigour of the key species is a good indicator of condition of the range as a whole. Sampson (1952) states that key species should be somewhat less preferred than so-called "sacrifice plants" which are very palatable but are never abundant. Usually 2 - 4 key species are chosen for use as indicators of proper utilization. In some cases one dominant may suffice and when this is judged to have been properly used ("maximum allowable defoliation without damage") it is assumed that the range as a whole should not be grazed further, but that stock should be moved.

2. Approach to ecological investigations on condition and trend

Irrespective of the region concerned, a number of basic questions need to be answered before any system of assessment of condition and trend can be applied in practice. These questions would usually include the following:

(1) Which species are present?
(2) Which species could or should be present?
(3) Which species dominate the community?
(4) Which species could or should dominate the community?
(5) Has the vegetation changed since domestic stock were introduced?
(6) If so, in what ways has it changed?
(7) Can the reasons for these changes be clearly identified?
(8) To what degree are the various species of plants utilized by animals?
(9) What is the relative productivity of the species present in terms of dry matter yield?
(10) What is the nutritive value of the species concerned?
(11) Are any species toxic or otherwise harmful to grazing animals?
(12) Which species are perennial and relatively stable in their annual production?
(13) Which combination of species is likely to give highest sustained animal production?
(14) Does this combination coincide with the "climax" vegetation of the area?

Many other questions could be added to the above, but in basic terms what is required to initiate the application of the concepts of condition and trend is, firstly, the determination of which species may be regarded as "desirable" in any area, and secondly, the assessment of how far removed the present vegetation is from the potentially "best" vegetation, as measured by its capabilities of sustained high animal production and maintenance of soil stability.

3. The need for condition and trend assessments

In semi-arid pastoral regions in which the replacement of natural grazing is not presently practicable on an extensive scale, animal production, and thus the viability of the rural community, is largely dependent on the productivity of the natural grazing. This being the case, it is necessary that the "state of health" and stability of this basic resource be maintained and, if possible, improved.

Because of the irreversibility of certain retrogressive changes in the vegetation and soil surface in many overgrazed semi-arid areas, it is of the utmost importance that the possibility of deterioration be carefully examined. Then, if required, the necessary recuperative measures can be taken before it is too late to stabilize the potential of the area at its natural level.

Acceptance of the above philosophy discounts short term "efficient" production as it is at the expense of the long term productivity of the natural resources. In this connection it is indeed striking to find that many young nations are apparently unable to learn the lessons of history, i.e. how almost invariably, the settlement era in semi-arid pastoral regions is accompanied by overoptimistic estimation of the carrying capacity of the land. This is followed by a realization of past mistakes, and this in turn by the unavoidable high cost of regeneration of damaged areas some of which can never be an economic investment.

The need for an ecological stocktaking at intervals in the Western Queensland situation is thus obvious and care should be taken to distinguish clearly between natural grazing land and other inputs in the rural production industry, since the former has very different characteristics and requirements from the other functions of production. Range condition assessment assumes that from a managerial point of view not only animals, but also plants and soil, have certain requirements which need to be met if high production is to be maintained. The world literature on production problems in semi-arid regions is dominated by the realization that much of the present day deterioration is a result of the sacrifice of ecological requirements of the natural resources in favour of short term economic and political expediency. For this reason there is a real need in many semi-arid areas to re-define a good manager and to legislate in an ecologically more purposeful manner. In the same vein, many

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democracies have had to distinguish between what the people want and what the people need, when legislating for conservation of unrenewable resources.

4. The criteria of condition and trend

If condition assessment is to be objective and meaningful, it must be based on measurable attributes which can be applied, on a quantitative basis, to a variety of sites. In addition, unless condition ratings can ultimately be related to management and a causal relationship established, condition and trend assessment can easily degenerate into no more than an academic exercise and may be what has been called "painful elaboration of the obvious".

Over the years, many criteria or indicators of condition have been proposed and used. Because the relative importance (and thus suitability) of the possible indicators differs according to the specific situation and the factors which are applicable to environments concerned, no single choice of indicator can be accepted as best for all cases. The following indicators have been used successfully in a variety of combinations, often with differential weighting applied to individual indicators:

(i) Plant criteria:
- a. Cover (% basal cover or bare soil)
- b. Botanical composition (% of various species present)
- c. Proportion of Annuals to Perennials
- d. Total number of species present
- e. Plants Age Classes
- f. Proportion of weeds
- g. Presence of relic vegetation
- h. Degree of hedging (browsing) of shrubs
- i. Accessibility of palatable species

(ii) Soil criteria:
- a. Degree of soil pedestalling
- b. Degree of soil movement
- c. Evidence of erosion pavements
- d. Degree of rill channel formation
- e. Abundance of litter or soil mulch
- f. Presence of active gullies
- g. Degree of alluvial deposition
- h. Presence of wind-scoured depressions

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All these attributes of the plant/soil complex are interrelated, and in combination they reflect the ecological status of the site concerned. However, the majority of these criteria may be used as symptoms which indicate the degree of imbalance in the ecosystem. The retrogressive chain-reaction, initiated by breakdown of cover through overgrazing, has been diagrammatically illustrated elsewhere by the writer (Roberts 1965a).

The range assessor is required to develop a condition rating score card based on those criteria which are judged to be basic attributes of the ecological status of the vegetation/habitat complex under consideration. It has been the writer's experience in many semi-arid regions that the criteria "botanical composition" and "percentage basal cover" are closely related and are sensitive measures of the status of many types of grazing land. In practice, botanical composition encompasses a number of other proposed plant criteria, e.g. proportion of annual plants, proportion of weeds, presence of relic vegetation and number of a species present. Measurement of basal cover (and thus of percentage bare area) reflects not only the density of the vegetation and the relative contribution of individual species to total basal cover, but is one attribute of the vegetation component of the system which directly controls the degree of splash erosion, soil movement and deposition as recognized in virtually all the soil criteria listed above.

The writer has put forward a simplified condition assessment scheme (Roberts 1970) based on cover, botanical composition, vigour and soil surface condition for use in open grassland.

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5. Requirements of a meaningful condition assessment system

As opposed to precise techniques of quantitative botanical analysis in which some form of point, line, quadrat or charting apparatus is used to determine botanical composition and cover, condition assessment schemes are usually required to be used for more rapid general estimation of the state of grazing land in the practical situation.

Thus, although the requirements of a successful condition assessment system may differ according to the aim of the assessment, the size of the areas concerned, and the manpower available, certain characteristics may be listed as basic to all successful systems. These would include the following:

a. Rapidity
b. Simplicity without loss of repeatability
c. Quantitative estimation of criteria
d. Applicability to grazed and ungrazed sites
e. Applicability in good and bad years (seasons)
f. Usefulness in guiding management decisions
g. Preferably but not necessarily acceptable to land users.

6. Prerequisites for successful application and interpretation of condition assessment

Although condition assessment methods have been developed to attain one of a number of different objectives, in the present study the field of alternatives has been narrowed down to the prevailing situation and priorities of land use as operating in Western Queensland at the present stage of development.

The fundamental tenets forming the basis of the approach employed in this study are as follows:

a. That animal production in Western Queensland will be based almost entirely on natural grazing land for the foreseeable future.

b. That this natural grazing land is dynamic and changes in response to climate and management.

c. That certain combinations of plants are more productive than others over the long term, through their particular acceptability to animals, nutritive value, productivity of dry matter and their ability to stabilize the soil as far as is possible under the edaphic and climatic conditions of the region.

d. That both the botanical composition and the density (cover) of the grass and herb component of the vegetation can be altered by management, within the primary control of climate.

e. That botanical composition and cover can be employed to deduce past treatment as well as to formulate management requirements for the future.

f. That the level of production of the natural grazing land may be influenced by management, only within the limits of the overriding effect of seasonal climate.

The rationale employed in this study stands or falls by the acceptance or otherwise of a causal relationship between the status of the plant/soil complex and management, within the framework of moisture availability. This being the case, the concept of condition here encompasses the overall level of ecological balance in the ecosystem and does not refer simply to the amount of feed available from a particular site at a given point in time.

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In the application of this dynamic ecological approach, clearly the correct estimation of site potential is essential for accurate and meaningful results, since all assessments using this approach are simply an attempt to judge the degree by which the present vegetation and soil situation deviates from the potential or possible best situation.

In developing a local assessment system based on local standards, decisions are required on at least four major issues, and in the following sequence:

a. The criteria of condition to be employed
b. The intensity and accuracy of sampling required
c. The actual scoresheet details
d. The weighting of criteria according to importance.

7. The definition and identification of "desirable" plant species

As one of the corner stones of condition classification, the use of botanical composition as a measure of condition, implies that differences exist in the "desirability" of the species which may be constituents of the grazing sward in any one area. While this is generally found to be the case, it is not necessarily so. However, for practical purposes it has been assumed that this difference exists in the majority of types of grazing land in semi-arid Queensland. The chances of a vegetation type, in its various successional stages, consisting of species, which are equally palatable, productive, nutritious and perennial are indeed remote.

The broad term "desirable species" has many and varied connotations, depending on the prime objectives of the classification applied. In this study, the following attributes are accepted as desirable, in the sense that they contribute to both the productivity and stability of the ecosystem;

a. Acceptability to grazing animals (palatability)
b. Productivity in terms of dry matter yield
c. Perenniality as reflecting soil stabilizing ability and both more permanent and uniform production
d. Drought tolerance
e. Nutritive value in terms of digestibility and protein content.

Most of these characteristics are difficult to gauge accurately and to class objectively, nevertheless a broad scale of high, medium or low may reasonably be applied, to all the characteristics.

Acceptance of a high rating on all of the above factors, as indicating highly desirable species, should not be misinterpreted as implying that species which fall short on one or more of these points are necessarily "undesirable". There are many species in Western Queensland which are very useful plants despite the fact that they are annual or that they lack drought tolerance or only have a low yield, e.g. Flinders grass, Button-grass and Native Sorghum to name but a few. It is accepted in this study, however, that highly productive, long-lived,

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drought tolerant, nutritious species are more conducive to stable long term animal production, because of their combined effect in reducing seasonal fluctuations in feed production and in preventing abnormally high soil losses.

Rather than classing species into discrete groups of "desirable" or "undesirable", by scoring them according to the above 5 attributes (with a maximum of 3 for each), each species may be rated from 1 to 15, assuming that the same species may sometimes be allocated different ratings in different sites relative to different associated species.

8. Field sampling for condition assessment

Basic to any form of reliable sampling is that it should be representative of the population as a whole while not being larger than is required for a predetermined level of accuracy. In American range parlance, the term "key area" is used to denote an area of a paddock which may be taken to reflect the degree of utilization of the paddock as a whole. Such a representative area would normally also typify the general edaphic and floristic conditions prevailing in the paddock overall. Sampling sites of the same type are required for condition assessment purposes and a multitude of suggestions on the methodology of sampling for this purpose have been proposed and published. Since circumstances dictate procedures, in the majority of cases it is left to the assessor to satisfy himself that his sampling assessment area:

a) Has the same ecological potential as the greater portion of the paddock being assessed.
b) Has been used to a similar degree by the grazing animals, as the paddock as a whole.
c) Is truly representative of the present condition of the paddock overall.

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9. The ecological basis of range judging

The original concepts of condition, trend and key species were developed under the climatic, soil and vegetation conditions of the western ranges of North America, where assessment systems have been developed for use in both arid and sub-humid range lands as well as in perennial and annual range types.

In the development of systems of range condition and trend, the identification of condition classes, which largely coincide with seral stages of secondary succession, has usually formed the accepted basis of distinction between classes. In this context, condition has been defined as "the percentage of the present vegetation which is original vegetation for the site" (Dyksterhuis 1949).

To employ this approach, implies firstly that a definite successional pattern exists in the area concerned and, secondly, that the "climax" vegetation can be identified. The term "climax" as used in condition assessment has the connotation of climatic, edaphic or physiographic maximum development of the vegetation and is generally accepted as equivalent to the "original" vegetation. Experience in the field has shown that the mono-climax theory cannot be meaningfully applied in condition assessment work.

Range sites (types, units) are regarded as different from each other when:

a) The species composition of their climax vegetation differs

or, b) The productivity differences between them justify different stocking rates.

It is generally found that there is a smaller variation between the various samples of relic ("original") vegetation on similar sites than there is within samples of the present vegetation on the same sites. The relics are the products of soil and climate (with or without fire), while present day vegetation, in the pastoral situation, reflects not only environmental influences but, superimposed within these natural controls, the affects of differential man-induced management through domestic stock.

In environments where the natural climax is forest, secondary succession would eventually lead to lower, rather

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than higher, carrying capacity in almost all cases. If condition classes are to be ecologically significant in timbered grazing lands, it is necessary to ascertain whether the climax is an open savannah or a closed forest, as both the ground cover and the grazing value of these two formation usually differ greatly. Many instances have been documented in which long periods of overgrazing have led to spectacular increases in the density of shrubs and trees in areas where the original vegetation was an open savannah.

Whereas the composition and cover of the climax may be covered by a single description in most sites, because there are many types (and causes) of retrogression, the characterization of deteriorated vegetation or poor condition will usually require a series of descriptions. Clements (1936) illustrated the dynamic principle of convergence, using the lower spokes of a wheel to indicate the numerous pioneer communities which might lead upwards to a similar climax representing the hub. Within this framework range ecologists developed the broad grouping of range plants into classes known as "increases, decreases or invaders", according to their reaction to heavy grazing. Whether or not these terms are employed, the assumption that all range plants fall into one of these classes has proved very useful in range judging in certain regions.

10. Inherent dynamic features of the Western Queensland situation which influence condition assessment standards

Because correct characterization of the climax is essential to any ecologically-based condition assessment system, uncertainty regarding the character of climax of necessity influences the confidence which may reasonably be placed in the assessment standards set for the area concerned.

As referred to earlier, western Queensland is subject to relatively large fluctuations in climate and because the troughs and peaks of this variation may continue for several consecutive years, the recognition of a single type of stable climax vegetation is less acceptable than in many other regions. The variability of the climate of this area has led to the acceptance by many workers of the view that the local vegetation is not only relatively unstable and in a "state of flux", but that it also has no single climax but rather a cycle of climax associations which is not necessarily progressive in the generally accepted seral connotation. Blake's (1938) words are pertinent in this regard: "The point which is desired to be stressed is that almost throughout Queensland the vegetation is of an unstable nature, so that it is frequently difficult to state what are seral and what are true climax communities. For western Queensland it has been shown that these changes are oscillating, not progressive. It is convenient to use the term 'fluctuating climax' to denote that condition which appears relatively stable but which is reality is in a state of unstable equilibrium. A true static climax may never exist.......The major communities concerned in the fluctuating climax may be termed 'complementary communities ......each of which is a climax under the existing set of conditions. What these conditions are is at present doubtful. Rainfall and, since settlement, stocking appear to be two of the factors concerned.....Whatever the actual cause it is scarcely necessary to stress the importance of the changes in relation to the carrying capacity of the country." Blake quotes the Blue grass and Mitchell grass communities as an example of a fluctuating climax in western Queensland.

As in many other semi-arid regions, distinguishing between the influence of climate (mainly drought) and the influence of management (mainly overgrazing) is a difficult problem in western Queensland. The world literature on grazing management in semi-arid regions repeatedly demonstrates how the quantitative results of management systems are often largely determined by the chance

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factor of seasonal climate which happened to prevail during the experimental period. In western Queensland the issue is complicated by the existence of different components of the vegetation which respond to winter and summer rains respectively, the winter component (non-grass herbs) increasing in importance in the southern districts.

11. The primary need for the establishment of local "ecological benchmarks"

From the foregoing it may be seen that before any system of condition assessment can be applied, it is necessary to develop standards concerning the species components of the seral stages of plant succession for each type of site, as well as to define "excellent condition" at least in terms of botanical composition and cover and to ascertain whether in fact such composition coincides with the climax for the type of site concerned. The unusually large variation in climate in this area may necessitate some modification of the classic Clementsian use of the terms "climax" and "stable". Rather than "seral communities", some local ecologists consider present vegetation more accurately described in terms of "stage of recovery" following the previous climatic disaster, and possessing no "stability" in the European ecological sense.

Clearly some method is required to determine how far the vegetation is able to develop floristically and cover-wise and then within the range thus established, to identify communities (seres) which correspond to condition classes ranging from poor to excellent. In such an investigation, a comparison is made of relic areas of "original" vegetation with areas displaying different floristic and cover values within the same type of site. In the semi-arid western Queensland situation the broad site types generally coincide with the major soil types within which a number of variations based on drainage differences may be distinguished.

The first facet of the present study was thus concerned with establishing which ground cover species occurred on the various major soil types and what variations in botanical composition and cover occurred in sample areas which had a history of some degree of protection from overuse, inasmuch as such sample areas exist in this region. It should, however, be emphasized that in the western Queensland situation, criteria such as abundance of topfeed and soil surface condition should also be included in overall range condition assessments.

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B. MODUS OPERANDI OF INVESTIGATIONS IN WESTERN QUEENSLAND

1. Study area:

The initial facet of the investigation into the possibilities of applying the concepts of "range condition and trend" in western Queensland concerned decision-making on the study area to be investigated. In view of the economic importance and geographic extent of the areas concerned, it was agreed that the present study be limited to the mulga and Mitchell grass country falling within the 10-20" isohyets.

2. Stocktaking of exclosures and other preserved areas

By means of personal contact with research workers, district advisers, leading graziers and others with a knowledge of the local area, a list was drawn up of the location of those areas of grazing land considered to be near to their "natural state" in the study area. These preserved areas had various case histories and, for a variety of reasons, had not been fully utilized in the past.

Apart from the above personal contacts, letters requesting information on the whereabouts of well preserved grazing land were placed in three Western newspapers and one state-wide Agricultural newspaper. In addition, enquiries were made from Queensland Railways, Department of Civil Aviation and the Flying Doctor Service about the existence of fenced and protected areas in the study area. The Irrigation and Water Supply Commission, supplied detailed maps of unwatered (and thus lightly utilized) paddocks in the shires concerned, while the Department of Lands was able to indicate properties which had been lightly stocked for a long period.

The writer then spent several weeks and travelled considerable distances attempting to verify the existence and case histories of the preserved areas brought to his attention by the above means. In a number of cases further investigation of certain sites was terminated as a result of conflicting evidence on the past treatment of the area or indications in the field that the site concerned was not representative or not botanically suitable for the purpose of establishing ecological benchmarks.

It should be emphasized here that the present study was to be completed in one year and that should this line of research be pursued, it would be advantageous to undertake a more searching quest for preserved areas than has been possible during the time available on this occasion. It will be appreciated that in a region such as the present study area, which has been settled since about 1870 (and which is very well watered by artesian bores and accompanying drains), genuine relic areas are almost non-existent while reasonably well protected areas, which have had the opportunity to develop to the limit set by the environment, are rare.

The writer has regarded grazing by wildlife and the occurrence of sporadic fires as integral facets of the natural environment and as such has regarded certain completely protected areas (such as Oestrus Paddock, "Gilruth Plains") as receiving unnatural treatment.

3. Planning of survey schedule

(a) Criteria and technique:

No large scale quantitative surveys of the ground cover of the vegetation of semi-arid Queensland have been recorded to date. In an attempt to eliminate subjectivity from vegetation recording in preserved areas, plant sociological criteria which could be quantitatively measured were used as the basis of the survey. Of the attributes which can be reliably measured, both botanical composition and percentage basal cover are generally accepted as being measures which are sensitive to change induced by treatment. As shown earlier, there is usually a direct relationship firstly between the dominant species and the density of the ground layer cover and secondly between the density of the cover and soil surface condition, soil loss and deterioration in general. Objective quantitative sampling for botanical composition and basal cover was accepted as the basis of the first phase of the present study. The technique selected was the point method, as widely accepted for measuring the criteria concerned in semi-arid grasslands (Winkworth, Perry and Rossetti 1962)* and as generally used in Queensland for detailed botanical survey in planted pastures. Because of the size of the areas to be covered and thus the need for a large-scale representative systematic sample, the usual point quadrat frame or bridge was replaced with the wheelpoint apparatus (Tidmarsh and Havenga 1955). An aluminium wheel point was designed and constructed locally. The apparatus gave sampling points 57" apart and used sharpened measuring spokes 3/16" in diameter (the diameter used in other point surveys by Department of Primary Industries in Queensland) and is shown in Plate 14 of Appendix A.

In view of the considerable volume of research undertaken on the woody plants of south west Queensland, the present study consciously emphasizes the grasses and herbs rather than the upper strata of the vegetation.

* Winkworth, R.E., Perry, R.A., and Rossetti, C.O., (1962) A comparison of methods of estimating plant cover in an arid grassland community. J. Range Mangt 15: 194-196.

(b) Survey sites:

After consideration of the suitability of all the possible preserved areas brought to the attention of the investigators, it was decided that the following 36 sites qualified for detailed botanical analysis during the autumn of 1972:

1. Railway reserve 571 rail miles from Brisbane, near Bierbank Siding on Charleville-Quilpie line.
2. Railway reserve 564 rail miles from Brisbane, near Cooladdi Siding.
3. Railway reserve 556 rail miles from Brisbane, near Yallamurra Siding.
4. Railway reserve 596 rail miles from Brisbane, near Winbin Siding.
5. Railway reserve 581 rail miles from Brisbane, near Cheepie Siding.
6. Road reserve, adjacent to railway reserve, 587 rail miles from Brisbane near Winbin Siding.
7. Railway reserve 601 rail miles from Brisbane, near Coolbinga Siding.
8. Railway reserve 604 rail miles from Brisbane near Winbin Creek.
9. Railway reserve 612 rail miles from Brisbane near Quilpie.
10. Railway reserve 567 rail miles from Brisbane, east of Bierbank Siding.
11. Charleville airfield
12. Yaraka airfield
13. Stonehenge airfield
14. Jundah common reserve paddock
15. Jundah racecourse enclosure
16. Jundah golf course
17. Windorah cemetery
18. Windorah airfield
19. "Wittenburra", Eulo. Hill paddock, west.
20. "Wittenburra", Eulo. Walls of China mountain.
21. "Wittenburra", Eulo. North eastern corner of Hill paddock.
22. "Bluegrass", Cunnamulla. Back paddock.
23. "Gilruth Plains", Cunnamulla. South Oestrus paddock reserve.
24. "Gilruth Plains", Cunnamulla. Immediately adjacent to site 23.
25. "Dingwall", Nebine. Front paddock.
26. "Woodvale", Nebine. Horse paddock.
27. "Boatman", Nebine. Mulga Density trial, plot A1, 40 trees/ha.
28. "Boatman", Nebine. Mulga Density trial, plot B3,640 trees/ha.
29. Wyandra airfield

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30. "[illegible] Park", Wyandra, north western paddock.

31. Railway reserve, near Glen Stuart siding on Blackall-Yaraka railway line.

32. Railway reserve, near Malvernton siding on Blackall-Yaraka railway line.

33. Railway reserve, between Malvernton and Benlidi sidings on Blackall-Yaraka railway line.

34. Railway reserve, at Benlidi siding on Blackall-Yaraka railway line.

35. "Koondoo" station, approx. 75 miles south of Blackall.

36. "Duneira" station, approx. 10 miles south of Blackall.

The past treatments, exact location and photographs of the survey sites are presented in Appendix A of this report.

4. Execution of Field Work

(a) Point data recording

At each survey site a transect ("run") of one half mile was used as the sampling unit. This sample gave a total of 500 points, each of which were examined for strikes on living plants at soil level or nearest species in the case of no strike being recorded. The accurate interpretation of the definition of a strike is important in both comparing the results obtained on various sites and in the comparison of the present survey with possible future re-surveys on the same sites. The original definitions as proposed for use with the wheel point apparatus were applied throughout (Tidmarsh and Hanenga, 1955 p 18).

The sample size of 500 points employed in this survey is sufficient only to give an estimate of percentage basal cover but gives reliable results in terms of floristics of the vegetation, expressed in terms of frequency of species as recorded from nearest plant data.

A pilot survey of the initial site (Site No. 11) indicated that, while four independent surveys of 500 points each by different workers gave relatively large differences in percentage basal cover figures, the botanical composition results based on nearest plants data were very similar.

(b) Plant identification

Accurate identification of species is basic to the collection of meaningful quantitative field data in botanical survey. In the present study a considerable amount of difficulty was experienced in identifying representatives of certain genera to species level, e.g. Bassia, Kochia, Sida, Abutilon, Eragrostis and Aristida.

In certain cases this was due to the need for taxonomic revision of the genera concerned, and in other cases it was caused by the lack of suitable flowering material for identification purposes at the time of survey (autumn).

For the purpose of this study, certain species which have both similar habitat requirements and similar ecological status, were combined for recording and analysis purposes, e.g. certain species of Aristida, Iseilema, Kochia and Bassia.

For field identification a portable (permanently plastic-covered) set of named specimens was developed, the originals having been identified by the Queensland Herbarium, Indooroopilly. Unknown species were given standard abbreviations for recording purposes until identification by the taxonomists concerned was available. Approximately 65 species of grasses and 95 species of non-grasses were recorded in the point survey results, excluding those species present but not recorded as strikes or nearest plants.

At each site notes were made on exact position, soil type, topography, tree population and history.

5. Analysis of Survey Data

Field data were recorded by entering species abbreviations for strike and nearest plant observations on recording sheets of paper containing 500 squares. The data were analysed by calculating the number of records of each species per site and expressing the results as a percentage. In this way both floristics and cover were reported on a percentage basis.

As occurs in most detailed quantitative studies of this kind, there was invariably a small percentage of seedlings which were too immature for positive identification. These were recorded as "Grass seedlings" and "Herb seedlings" respectively although they seldom constituted more than 1% of the botanical composition of any site.

Although it is appreciated that annuals cannot be regarded as permanent components of the vegetation in terms of longevity, failure to include annuals in this study would certainly lead to an inaccurate record of the present floristics of the sites concerned, particularly from a fodder production point of view when the nutritional importance of genera such as Dactyloctenium, Iseilema and Aristida are considered.

Although only 36 sites have been studied, the type of data accumulated is suitable for a variety of mathematical processing procedures as applied in present day numerical taxonomy (Roberts, 1967). For the immediate purposes of the present investigation, however, simple computation of dominants and sub-dominants for the individual sites and groups of similar sites is sufficient.

By comparing the results obtained on preserved areas with the results obtained on sample areas which have been subjected to heavy grazing for continuous long periods, an indication may be obtained of the degree of change in both cover and floristics which has taken place in this region. The present survey results have been collected and analysed in an attempt to establish some form of ecological benchmark for vegetation comparison purposes on similar sites in the future.

Since no more detailed local site descriptions than Northcote's Atlas of Australian Soils (Isbell et al, 1967) exists at present, until the present Land Utilization Survey (D.P.I. 1972) results are available, only broad grouping of sites on a superficial basis is possible, e.g. sandy red soils, heavy clay soils, lateritic earths and rocky dissected sites. These groupings coincide with Northcote's units designated as MY4, CC19, MY1, and FZ1 respectively. These symbols represent the dominant soil group in each of Northcote's mapping units.

To assist in data interpretation and later location of sites, each site was photographed and duplicate sets of photographic records have been filed with the Department of Primary Industries.

Transference of species data from the survey sheets to punched cards, from which species were classified by a hierarchial procedure on the basis of individual attributes, made it possible to draw up species lists for use in condition assessment. Analysis of the data in such a way that the dominants could be extracted provides an additional basis for condition rating. The term dominance is used here to denote numbers of plants and is not related to physiognomy.

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6. Presentation of Survey Results

The summarized results of 36 half mile transects are present in the Appendix A giving location, sample position, descriptive notes and history of each survey area. Photographs of each survey site are appended and may be used in relocating sites if necessary.

The number of species recorded in each survey is correct only to the degree of accuracy allowed by taxonomic identification of recorded plants to species level.

7. Summary of survey results

Examination of the summarised results of the field work exposes three main findings (See Table 3):

(a) Basal cover is relatively low.

(b) The number of species varies greatly between sites.

(c) The numerical dominants are similar on similar soil types (See section D.).

The basal cover figures tend to be related to soil type and average 3.3% on hard laterites, 4.4% on sandy red earths, 1.1% on rocky plateaux and 3.0% on cracking clays. These results suggest that the lighter the texture of the soil, the greater is the potential basal cover which may be expected to develop. Statistical tests (Tidmarsh and Havenga 1955) indicate that the average basal cover on sandy red earths and laterites is significantly ($P = .05$) higher than on rocky plateaus, but not significantly higher than on cracking clays.

The number of species present is mentioned earlier as a criterion which has been used in condition assessments in the past by range assessors. The present survey indicates that while the rocky plateau soils support a ground cover consisting on average of only 13 species, sandy soils average 20 species, clay soils 25 species and laterites 31 species.

Table 3 Summary of survey data at 36 sites

Laterites Site No.	No.Species	% Basal Cover	Rocky Plateau Soils	No.Species	% Basal Cover
1	27	1.7	Site No.6	17	0.8
2	33	6.0	20	16	0.8
3	43	3.2	26	7	1.8
4	28	2.0	Av.	13	1.1
5	32	6.2			
7	30	3.8	Cracking Clays		
10	31	1.0	Site No.8	35	2.0
21	25	0.6	12	37	0.8
Av.	31	3.3	13	31	1.6
			14	19	1.2
Sandy red earths			19	21	0.2
			22	25	3.0
Site No.9	21	3.8	23	29	1.8
11	27	3.6	24	26	2.4
15	23	1.2	30	12	7.6
16	21	3.2	31	18	3.8
17	19	7.2	32	17	5.4
18	18	11.2	33	20	3.2
25	18	3.8	34	31	3.4
27	17	5.4	35	27	5.2
28	18	1.4	36	22	3.4
29	22	3.4	Av.	25	3.0
Av.	20	4.4			

In evaluating the present results, the degree to which the survey sites represent the main vegetation types of western Queensland requires examination. In general terms the surveys cover most of the important local types except the hard mulga ridges where ground cover is sparse and runoff is very high. This deficiency cannot be made good until suitably preserved sites are brought to the notice of research workers.

As mentioned earlier, it is very doubtful whether any of the sites studied can be claimed to represent pristine or original vegetation for the site concerned. Nevertheless, this investigation does represent the best data available for the particular situations concerned at this point in time.

Whereas the contribution of ephemerals to the floristics of the samples chosen will vary widely according to seasonal rainfall, the perennial components of the botanical composition lists may give a useful basis for future comparisons. The assessment of condition of each site would be enhanced by detailed records of tree density, topfeed availability and soil surface condition (Roberts, 1970). Despite the fact that only two criteria have been used in this study, it should be emphasized that the collection of data on such basic measures as cover and botanical composition in an objective, quantified manner from large systematic samples, provides reliable basic data. The use of close-up stereo photography as an aid to botanical changes (Wimbush et al., 1967) could make a real contribution to the plotting of vegetative changes with time.

The greatest use could be made of these surveys if some guarantee of continued preservation, or at least documented treatment, of the sample sites could be obtained.

In summarizing the results of the field work it should be stressed that despite a concerted effort to find suitably protected or lightly grazed areas in the Mitchell grass country between Blackall and Longreach (which is one of the two regions covered by the terms of reference of this investigation), very few such sites were found. The field work carried out concerned only the establishment of cover and floristic standards for each major soil type, but did not include condition assessments in representative heavily utilized paddocks in western Queensland. The latter expansion of the investigation requires attention before the potential usefulness of condition and trend concepts can be gauged. This second phase of the work would include the development of a locally adapted condition assessment score card, as is being attempted presently in Central Australia (Lendon, Latz and Foran, 1972).

C. STEPWISE PROCEDURE FOR DEVELOPMENT OF CONDITION STANDARDS IN WESTERN QUEENSLAND

1. General

In North America where the concepts of range condition and trend originated, and in South Africa where a similar approach but different terminology has been used, successional stages generally coincide with productivity classes. Under such circumstances, both soil protection and forage yield increase with successional stage. As a practical rule-of-thumb, if the vegetation consists of more than 75% of climax species, it is classed as "excellent", while less than 25% climax species is classed as "poor". The classes of "good" and "fair" are used as intermediates and all four classes indicate present condition relative to potential botanical composition.

Broadly speaking, when climax vegetation is overgrazed, certain species are reduced or even disappear. These species are referred to as "decreasers". Conversely those plants which tend to dominate when the climax is overgrazed are termed "increasers". When overgrazing continues sufficiently long for these increasers to eventually decline in number, their place is taken, in turn, by so-called invaders, which are often inedible species.

In certain regions, such as the Highveld of South Africa, the climax vegetation is neither the most productive nor the most desirable. In such instances, where unproductive (in the grazing sense) woodland or forest is the climax, range condition is not judged simply on floristics of successional stages, but rather on the proportion of nutritious, high producing, palatable, perennial and accessible species present. This assessment is made irrespective of the supposed successional positions of the species concerned. Useful guides to condition can be drawn up for a variety of range sites by including density of the ground layer plants, litter and soil surface condition and percentage of "desirable" species present.

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In its simplest form, the field work involved in condition assessment consists of three steps:

1. Mapping of range sites (or natural pasture types) into units having the same potential. Vegetation, soil and topography all contribute to the homogeneity of range sites (= "types of country" in W.Qld).
2. Sampling of the vegetation and recording of botanical composition, and other criteria included in the score sheet.
3. Assessment of paddocks (or samples, areas, properties) on the basis of condition classes.

2. Plant groups for condition assessment in western Queensland

Surveys undertaken during the present investigation enabled lists to be drawn up of the dominant and sub-dominant species which occur in protected areas, within each type of vegetation or range site. In this case sites are differentiated mainly on the basis of soil differences, e.g. lateritic red earths, sandy red earths, cracking clays and lithosols (rocky plateau soils). The numerical dominants (species making up more than 1% botanical composition) as extracted from the botanical surveys are summarised below:

NUMERICAL DOMINANTS (EX SURVEYS)

Grasses	Other Plants
1. On Laterites	
Aristida jerichoensis	Acacia aneura
Danthonia bipartita	Abutilon sp.aff.A. otocarpum
Digitaria ammophila	Bassia spp.
Dichanthium sericeum	Chenopodium rhadinostachyum
Themeda australis	Chenopodium spp.
Tripogon loliiformis	Eremophila gilesii
	Evolvulus alsinoides
	Fimbristylis dichotoma
	Goodenia lunata
	Heliotropium tenuifolium
	Kochia spp.
	Minuria integerrima
	Sida sp.

2. <u>On Sandy Red soils</u>

Aristida contorta	Abutilon spp.
A. jerichoensis	Boerhavia diffusa
Danthonia bipartita	Cheilanthes sieberi
Eragrostis eriopoda	Evolvulus alsinoides
Enneapogon polyphyllus	Kochia spp.
Triodia basedowii	Portulaca sp.aff.P.oleracea
	Sida spp.

3. <u>On Rocky Plateaux</u>

Amphipogon caricinus	Eremophila bowmanii
Eragrostis eriopoda	Eremophila latrobei
Eriachne mucronata	Kochia spp.
Neurachne mitchelliana	Minuria integerrima
	Sida sp.

4. <u>On Cracking Clays</u>

Aristida latifolia	Abutilon malvifolium
Astrebla elymoides	Atriplex muelleri
Astrebla lappacea	Bassia spp.
Brachyachne convergens	Boerhavia diffusa
Dactyloctenium radulans	Chenopodium spp.
Dichanthium sericeum	Cyperus bifax
Eragrostis setifolia	Desmodium spp.
Iseilema spp.	Goodenia spp.
Panicum queenslandicum	Hibiscus trigonum
Sporobolus actinocladus	Malvastrum spicatum
	Minuria integerrima
	Phyllanthus maderaspatensis
	Polymeria marginata
	Portulaca filifolia
	Portulaca sp.aff.P. oleracea
	Rhynchosia minima
	Salsola kali
	Sida spp.
	Solanum esuriale
	Trianthema triquetra

The lists of dominants recorded in the protected areas may or may not be **truly** representative of the herbaceous layer in its most well developed state. These surveys cannot claim to have quantified the floristics of the "climax", but do give an indication of the quantified relations between the "desirable" species which are potentially important on each major soil (and thus pasture) type in this region (Compare Appendix A with Table 4). The surveys indicate what contributions individual species are capable of making in terms of both basal cover and percentage of botanical composition. While the absolute values for these basic criteria will vary from year to year on the same site, particularly as a result of the response of annuals to seasonal rainfall, the percentages recorded for the perennial fodder plants are the only quantitative standards of floristics of the pasture plants available for this region at present.

3. Identification of "desirable" species and key species

Despite the shortcomings of the available "standards" of pasture potential, and the qualifications which need to accompany the use made of the field survey data, an attempt has been made to group the grasses into "value classes". By making a study of the existing literature on the plants of the area concerned, it has been possible to develop a punched card index on the vegetation. The cards were punched for pereniality, productivity, soil association, moisture requirements, acceptability to animals, frequency on overgrazed areas and chemical composition. The 80 grass species which have been included in this cardex are apparently not yet all well documented in the literature as far as the above attributes are concerned, thus tentative estimates have had to be made concerning the acceptability to stock of certain species.

By categorizing the individual species (on the basis of pereniality, acceptability and productivity) into "desirable" and "less desirable" classes, some form of objective distinction between the better grasses and the others has been arrived at. The tabulated information on those grasses which are of general occurrence on each of the major soil types of this area is given in the following Table 4. It should be stressed that the information summed up in this table is the collated result of a study of the available published knowledge on the grasses concerned. The works of the following authors have been included: Allen, 1944; Anson, 1965; Bailey, 1902; Beadle, 1948; Biddescombe, 1953; Blake, 1944; Breakwell, 1923; Burr, 1955; Burrows and Beale, 1970; Condon, Newman and Cunningham, 1969; Ebersohn, 1964; Ewart, 1917; Everist, 1935; Everist, 1958; Hubbard, 1928; Laxarides, 1970; Maiden, 1889; McBarron, 1955; McDonald, 1908; Moore, 1970; Newman, 1969; Perry, 1962; Purcell, 1963; Purcell and Lee, 1970; Roe, 1941; Siebert, Newman and Nelson, 1968; Snook et al, 1965; Wilcox, 1960; Whalley, 1968; and White, 1935. A number of these sources have been summarized by Cameron (1961).

Since published information on the attributes of the non-grasses of this area is lacking, only the grasses have been employed in attempting to arrive at key species.

Table 4: Evaluation of grass species characteristic of the main soil types in western Queensland

1. Lateritic soils

	Per.*		Over-	Accept.			Prod.			Moister
	Ann.	Per	graz.	H	M	L	H	M	L	habitat
Amphipogon caricinus		+				+		+		
Aristida contorta	+		+		+			+		
Aristida jerichoensis		+			+		+			
Cymbopogon obtectus		+				+	+			+
Dactyloctenium radulans	+		+	+				+		
Danthonia bipartita		+		+				+		
Dichanthium sericeum		+		+			+			+
Digitaria ammophila		+		+			+			
Digitaria brownei		+		+				+		
Eragrostis elongata		+			+			+		
Eragrostis eriopoda		+			+			+		
Eragrostis lacunaria		+			+			+		
Eragrostis parviflora		+			+		+			+
Eriachne pulchella		+			+				+	
Enneapogon polyphyllus	+			+				+		
Eulalia fulva		+		+			+			+
Neurachne mitchelliana		+		+			+			
Neurachne munroi		+			+			+		
Panicum decompositum		+			+		+			
Themeda australis		+			+		+			+
Themeda avenacea		+			+		+			+
Tragus australianus	+		+		+				+	
Tripogon loliiformis	+		+		+				+	

* Per = Perenniality
Overgraz = Typical of overgrazed sites
Accept = Acceptability to domestic stock
H, M, and L = High, Medium and Low
Prod = Productivity

2. Sandy Red Soils

Species	Per.*		Over	Accept			Prod.			Moister
	Ann	Per	graz	H	M	L	H	M	L	habitat
Aristida browniana		+			+			+		
Aristida contorta	+		+	+				+		
Aristida ingrata		+		+			+			
Brachiaria gilesii	+			+					+	+
Brachiaria piligera	+			+				+		
Brachiaria miliiformis	+			+					+	
Chloris dichanthoides	+				+			+		
Chloris pectinata	+			+				+		
Chrysopogon fallax		+		+			+			
Cymbopogon obtectus		+			+		+			
Dactyloctenium radulans	+		+	+				+		
Danthonia bipartita		+		+				+		
Digitaria ammophila		+		+				+		
Digitaria brownei		+		+				+		
Enneapogon avenaceus	+		+	+				+		
Enneapogon polyphyllus	+			+				+		
Eragrostis elongata		+			+			+		
Eragrostis eriopoda		+		+				+		
Eragrostis lacunaria		+			+			+		
Eragrostis parviflora		+			+			+		+
Eriachne aristideae		+			+			+		
Eriachne helmsii		+			+			+		
Neurachne mitchelliana		+		+			+			+
Neurachne muelleri		+			+			+		
Panicum decompositum		+			+		+			
Paspalidium constrictum		+			+			+		
Perotis rara	+		+		+				+	
Themeda australis		+			+		+			+
Triodia basedowii		+				+	+			
Triodia marginata		+			+		+			
Tripogon loliiformis	+		+			+			+	
Triraphis mollis		+	+			+	+			

3. <u>Rocky Plateaux</u> (lithosols)

	Ann.	Per.	Over graz	Accept. H	Accept. M	Accept. L	Prod. H	Prod. M	Prod. L	Moister habitat
Amphipogon caricinus		+				+		+		
Eragrostis eriopoda		+		+				+		
Eriachne mucronata		+				+		+		
Neurachne mitchelliana		+		+			+			+

4. <u>Cracking Clays</u>

	Ann.	Per.	Over graz	Accept. H	Accept. M	Accept. L	Prod. H	Prod. M	Prod. L	Moister habitat
Aristida latifolia		+			+		+			
Astrebla elymoides		+		+			+			
Astrebla lappacea		+		+			+			
Astrebla pectinata		+		+			+			
Astrebla squarrosa		+			+		+			+
Bothriochloa ewartiana		+		+			+			+
Bothriochloa **bladhii**		+			+		+			+
Brachyachne convergens	+		+	+				+		
Brachiaria miliiformis	+				+			+		+
Chloris acicularis		+		+				+		+
Chloris divaricata		+			+			+		
Chloris pectinata	+			+				+		
Chloris truncata	+				+			+		
Chloris scariosa	+				+			+		
Cynodon dactylon		+	+	+				+		
Dactyloctenium radulans	+		+	+					+	
Dichanthium sericeum		+		+			+			+
Diplachne muelleri		+			+		+			+
Digitaria ammophila		+		+				+		
Enneapogon nigricans	+				+			+		
Enneapogon polyphyllus	+			+				+		
Eragrostis **tenellula***	+				+				+	
Eragrostis microcarpa	+				+				+	+
Eragrostis parviflora		+			+		+			
Eragrostis setifolia		+			+			+		
Eragrostis leptocarpa		+			+			+		+
Eragrostis tenellula	+				+			+		
Eragrostis xerophila		+		+				+		
Eriochloa pseudoacrotricha	+			+			+			+
Eriochloa australiensis	+			+				+		+

*** = <u>E.</u> <u>japonica</u>**

contd.

Cracking Clays Contd.

	Per.		Over	Accept.			Prod.			Moister
	Ann.	Per.	graz	H	M	L	H	M	L	habitat
Echinochloa turnerana	+			+			+			+
Eulalia fulva		+		+			+			+
Iseilema spp.	+		+	+				+		
Leptochloa digitata		+				+	+			+
Panicum decompositum		+			+		+			
Panicum buncei	+				+			+		
Panicum whitei	+				+		+			+
Paspalidium globoideum	+			+					+	+
Sporobolus actinocladus		+	+	+				+		
Sporobolus mitchellii		+				+			+	
Sporobolus caroli		+		+					+	
Themeda avenacea		+			+		+			+
Tripogon loliiformis	+		+		+				+	
Triraphis mollis		+	+			+		+		

At present, too little information is available on the reaction of local plants to grazing to determine which species are increasers and which are decreasers. However, if such a classification is desired, two approaches may be used. Firstly, defoliation studies can indicate which species are unable to withstand intensive grazing and which consequently may be expected to decrease and ultimately disappear under continuous grazing. Secondly, areas of grazing land which have been differentially treated for known periods can be botanically surveyed and their floristics compared with protected or well preserved areas within the same type of site (or soil, in the present case). Although care should be taken to make allowance for the effects of climatic variability in making the above comparisons, the latter method is likely to be the more useful in many cases. The former method has the advantage of isolating the defoliation effect from the climatic effect, but may lead to difficulty in extrapolating to the field situation where the effects of trampling, drought and insects require recognition.

A search for study areas of known management history is thus required before existing information in western Queensland can be expanded to the degree required for a meaningful attempt to be made to make condition assessments locally. At the same time it should be stressed that strictly speaking, present condition need not necessarily be the result of management, but may reflect rather the cumulative effect of the climatic history and the occurrence of chance ecological events such as fires, locust attack, termite activity and use by wild life. In particular, the influence of insects on the ecosystem of semi-arid Australia may easily be understated. Frith (1970) is of the opinion that the effect of termites, ants and grasshoppers is "probably of greater significance than that of the vertebrate fauna".

Extracting the main groups of grasses from the tabulated information, the following lists of possible key species have been drawn up for each main soil type, based on perenniality, acceptability (estimated palatability), production and general abundance (the other stated attribute of key species, i.e. reasonable resistance to grazing, is not known at present and cannot be used in their selection at this stage):

1. On Laterites
   - Danthonia bipartita
   - Dichanthium sericeum (moist sites)
   - Digitaria ammophila
   - Digitaria brownei
   - Eragrostis eriopoda
   - Eulalia fulva (moist sites)
   - Neurachne mitchelliana
   - Neurachne munroi
   - Panicum decompositum
   - Themeda australis
   - Themeda avenacea (moist sites)

2. On Sandy Red Soils
   - Chrysopogon fallax
   - Danthonia bipartita
   - Digitaria ammophila
   - Digitaria brownei
   - Eriachne aristideae
   - Eragrostis eriopoda
   - Neurachne mitchelliana
   - Panicum decompositum
   - Themeda australis
   - Triodia marginata

3. On Rocky Plateaux
   - Eragrostis eriopoda
   - Neurachne mitchelliana

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4. On Cracking Clays

Astrebla elymoides
Astrebla lappacea
Astrebla squarrosa (moist sites)
Bothriochloa ewartiana
Chloris acicularis
Dichanthium sericeum
Digitaria ammophila
Eragrostis setifolia
Eulalia fulva
Panicum decompositum
Sporobolus actinocladus
Themeda avenacea (moist sites)

The lack of quantitative information on the attributes of individual species,at the present level of knowledge, clearly necessitates the use of some "intuition" in drawing up the above lists. Under the circumstances, key species listed should be regarded as no more than a basis for further critical investigation and a pointer to gaps in current knowledge.

Considering the proposed use of key species in management decision-making, it should be reiterated that theoretically key species should be less palatable than the very palatable "sacrifice plants" (if these are present at all). The main use of key species is, as defined earlier, to act as a barometer of proper use level, i.e. the correct level or intensity of grazing of the key species is accepted as the correct level for the vegetation as a whole. Alternatively overgrazing of the key species indicates overgrazing of the vegetation (paddock) as a whole.

In addition, the proportion that all the key species (together) make up of the overall botanical composition should be directly related to the total forage yield of the vegetation. If this is not the case, the key species have been chosen incorrectly. Apart from botanical composition, the vigour of the key species should reflect the general state of health of the vegetation.

The practicability of these applications of the key species concept in assessing condition and trend of grazing land in western Queensland may now be considered, assuming that in practice not more than five key species are employed. The species listed above all qualify in broad terms for use as key species; however, further information is required on relative acceptability and ability to withstand defoliation before "short lists" of the 2-4 indicator key species are finally selected for trial condition assessments in the field.

4. Characterization of successional stages

Referring to the definition by Parker (1954) as stated earlier, condition classes are essentially successional stages as influenced by grazing, while the most healthy state of the vegetation is an optimum state for soil stability, pasture quality and vegetation development. Theoretically, this implies the drawing up of standards of floristics, cover, vigour and soil surface condition for each site type (grazing land type). Site types are differentiated on the basis of differences in botanical composition of their climaxes and on inherent productivity differences large enough to justify different potential stocking rates.

The effect of seasonal rainfall in deflecting successional development in this region has been referred to earlier (Everist and Moule, 1952). There is evidence that, depending on the amount and season of rainfall following overgrazing, clearing or burning, alternative species or groups of species may dominate in the years following such treatment. If the same duplicity applies to seral development following spelling of degraded areas, then some form of multiple but parallel successional patterns may exist. Ecological studies on each of the major soil types of western Queensland should clarify this important issue and in view of the universality of seral development, it may be expected that predictable successional patterns do exist, irrespective of whether the final stage is stable, fluctuating or cyclic. Numerous Australian writers have inferred that seral development operates in semi-arid areas (Anderson, 1941; Blake, 1940; Burrows, 1971; Chippendale, 1963; Griffiths Davies, 1955; Hall et al, 1964; McTaggart, 1936; Moore, 1960; Moore, 1969; Nunn, 1960; Osborn, 1928; Perry, 1968; Pidgeon and Ashby, 1940; Roe and Allen, 1945; Suijdendorp, 1955; Wilcox, 1960; Williams, 1968a; Williams et al, 1969; Winders, 1936 and Wood, 1936). Several writers have published detailed successional patterns in which the status of the plants concerned is designated (Beadle, 1948; Costin, 1967; Ebersohn, 1967; Holland and Moore, 1962; Jessup, 1951 and Davidson 1954). A good recent example of seral pattern diagrams is given by Moore (1970).

/80.

In attempting to identify particular plants with different stages of development of the vegetation, it is necessary first to specify the characteristics typical of the members of each stage, or at least of the two extreme stages. Pioneers are universally typified by some or all of the following features:

High seed production
Production of light (windblown) seed
Ability to germinate at high or wide range temperatures
Ability for seedlings to survive desiccation
Fast growth rate
Short life cycle (annual, ephemeral)
Prostrate growth habit
Small size of plant

"Climax" species on the other hand are generally long-lived, persistent perennials which are able to dominate the vegetation and control the entry of seasonal annuals. These climax plants often possess most of the following features:

Ability to establish and complete ecesis in an existing colony of pioneers
Ability to form a relatively dense perennial cover
Deep widespread root system
Ability to survive drought and utilize high moisture levels
Taller growth habit than most local ephemerals

Although local information on many of the above features is deficient or fragmentary, the following successional patterns (Table5) have been drawn up on the basis of the writer's short term observations. Clearly further study of the local situation will lead to a number of modifications in these proposed seral positions of individual species.

Table 5: Suggested seral patterns in western Queensland

1. On Laterites

"CLIMAX" SPECIES

Amphipogon caricinus
Cymbopogon obtectus (postclimax)
Danthonia bipartita
Digitaria ammophila
Digitaria brownei
Dichanthium sericeum
Eulalia fulva
Neurachne mitchelliana
Themeda australis
Themeda avenacea (postclimax)

↑ ↓

Eragrostis eriopoda
Eragrostis lacunaria
Eriachne pulchella
Neurachne munroi
Panicum decompositum

↑ ↓

PIONEERS

Aristida jerichoensis
Aristida contorta
Dactyloctenium radulans
Enneapogon polyphyllus
Tragus australianus
Tripogon loliiformis

2. On Sandy Red Soils

"CLIMAX" SPECIES

Chrysopogon fallax
Cymbopogon obtectus
Danthonia bipartita
Digitaria ammophila
Digitaria brownei
Neurachne mitchelliana
Themeda australis
Triodia basedowii
Triodia marginata

↑↓

Aristida browniana
Chloris dichanthoides
Enneapogon avenaceus
Eragrostis elongata
Eragrostis eriopoda
Eriachne helmsii
Panicum decompositum

↑↓

PIONEERS

Aristida contorta
Aristida jerichoensis
Brachiaria spp.
Chloris pectinata
Dactyloctenium radulans
Enneapogon polyphyllus
Eriachne aristideae
Perotis rara
Tripogon loliiformis
Triraphis mollis

/83.

3. <u>On Rocky plateaux</u>

"CLIMAX"
SPEICES

Amphipogon caricinus
Danthonia bipartita
Eriachne mucronata
Neurachne mitchelliana

↑ ↓

Aristida jerichoensis
Eragrostis eriopoda

↑ ↓

PIONEERS

Aristida contorta
Enneapogon polyphyllus

Solanum ellipticum
Kochia spp.
Bassia spp.
Heliotropium tenuifolium
Euphorbia drummondii

4. On Cracking Clays

"CLIMAX" SPECIES

Astrebla elymoides
Astrebla lappacea
Astrebla pectinata (rare)
Astrebla squarrosa (postclimax)
Bothriochloa intermedia
Dichanthium sericeum
Eulalia fulva

↑ ↓

Chloris acicularis
Eragrostis setifolia
Eragrostis xerophylla
Panicum decompositum
Sporobolus actinocladus

↑ ↓

PIONEERS

Aristida latifolia
Brachyachne convergens
Chloris truncata
Dactyloctenium radulans
Enneapogon nigricans
Iseilema spp.
Sporobolus caroli
Tripogon loliiformis

Atriplex muelleri
Bassia spp.
Boerhavia diffusa
Portulaca spp.
Salsola kali
Sida spp.
Solanum esuriale
Threlkeldia proceriflora

Table 5 includes non-grasses only in certain cases. In some cases certain woody plants appear to act as both pioneers and climax species and with the information available it is not possible to allocate many of the species to a seral position. In the case of the grasses, it is doubtful whether certain species can be grouped according to discrete classes since in several cases the distinction between pioneer and sub-climax plants is not clear-cut.

D. EVALUATION AND DISCUSSION

Having presented and summarized the results of the field work, certain basic essentials stipulated earlier under section A.6. "Prerequisites for successful application and interpretation of condition assessment" require evaluation.

Firstly, both the field surveys and the information from the literature indicate that it is possible to identify certain combinations of plants which are more productive than others, based on the attributes shown in the foregoing tables.

Secondly, observational comparison of the protected survey sites with adjoining areas with a known history of heavy utilization suggest that both botanical composition and cover can be changed by the treatment which is applied. (A comparison of Site No. 30, managed intelligently with sheep, with neighbouring areas is a particularly good illustration of the effect of treatment on "range condition" notwithstanding large climatic fluctuations).

Thirdly, the information accumulated indicates that the condition criteria employed may well be used to deduce, at least partially, past treatment and to guide future management, if only in terms of the need for spelling aimed at seedling regeneration. However, an unqualified answer cannot be given to the question of whether a causal relation has been established between management and condition, by this study. It would appear that the ground layer of vegetation is relatively more prone to drought effects on certain soils than on others. From this it may be inferred that the comparative influences of drought and management, on current condition of the natural grazing land, vary between soil types.

Referring back to the questions which require answers before condition assessments can be made (See "Approach to ecological investigations on condition and trend."), an attempt may now be made to answer these.

(1) The current dominants in normally grazed communities have not been quantified in this study and await documentation.

(2) The species which could or should dominate have been identified and recorded in limited samples of each major grazing land type.

(3) The data required to determine which species are present under continuous use in each grazing land type can be obtained only by extensive field surveys of western Queensland.

(4) The species which could or should be present are indicated by the survey results. These data, representing 500 readings for floristics and covering a total distance of 18 miles, are a meaningful record of the overall quantitative relations on plant numbers as they occur today. It is true that many of the sites surveyed are not an accurate reflection of potential vegetation development on the soils concerned. At the same time, it would be difficult, in view of the lack of more suitable protected sites, to demonstrate alternative conclusions on the basis of numerical data.

(5) The possibility that vegetation has changed since stock were introduced cannot be shown from the survey site data as such, however, a cursory examination of adjoining areas suggests that initiation of the type of surveys suggested under (3) above would expose treatment effects.

(6) The ways in which the vegetation may have been changed would emerge from the above-mentioned surveys of heavily grazed areas. Without wanting to for go the results of such comparative surveys, the writer's observations in western Queensland indicate a general decrease of palatable perennial grasses leading to either a lower total ground cover or replacement by annual grasses and herbs, depending on soil type and rainfall. The numerically important species in overgrazed areas are indicated in the tabulated information from the literature presented in Table 4.

(7) In distinguishing stocking effects from drought effects on the vegetation, documented histories of comparable sites are required. In the case of certain of the survey sites, sufficient information is available to differentiate the effects of known grazing treatment from the effect of climatic fluctuations.

(8) The degree to which the various species are utilized by animals has been extracted and summarized from existing information. This information on the grasses is presented in the foregoing tables. Similar information on the non-grasses is less complete.

(9) Relative productivity data is deficient and at present productivity can only be estimated from the relative morphologies of the species concerned, as indicated in the tables of grass values (Table 4).

(10) The nutritive values of local grass species have been summarized above in tabular form (Table 6) from available published data but the majority of plants have not been chemically analysed at this stage.

Table 6 : Chemical Composition of a selection of Grasses of western Queensland (Allen, 1944; Siebert et al, 1968; Newman, 1969)

Species	% Crude Protein*	% Crude Fibre
Aristida contorta	8 (5-11)	25 (24-27)
Astrebla elymoides	12 (6-19)	-
Astrebla pectinata	5 (4- 7)	27 (26-28)
Brachyachne convergens	15 (10-20)	-
Chloris acicularis	8 (5-12)	25 (20-30)
Dactyloctenium radulans	10 (5-15)	20 (17-23)
Danthonia bipartita	16 (16)	-
Digitaria ammophila	7 (3-12)	23 (18-28)
Digitaria brownei	5 (4-7)	33 (23-45)
Enneapogon polyphyllus	6 (5-7)	26 (23-29)
Eragrostis eriopoda	4 (3-6)	28 (26-31)
Eragrostis setifolia	6 (4-8)	28 (23-32)
Eragrostis xerophila	6 (5-7)	27 (24-31)
Eriachne helmsii	13 (13)	-
Eulalia fulva	7 (7)	-
Neurachne mitchelliana	18 (18)	-
Panicum whitei	12 (5-20)	-
Themeda australis	4 (3-6)	26 (25-28)
Tragus australianus	9 (5-13)	18 (13-25)
Triodia basedowii	4 (2-7)	28 (25-32)
Tripogon loliiformis	10 (9-12)	20 (19-22)
Triraphis mollis	10 (10)	-

* The figures represent analyses of each species on various soil types and at various growth stages. Average percentages as well as the range of values quoted are given in the table.

By and large the data for chemical composition are not sufficiently comprehensive to allow for the use of this criterion in grouping the grasses in value classes. Present research into the digestibility of the grasses concerned should assist in such a classification.

(11) The most important poisonous and toxic plants are known and have been documented in the past. A list of such plants is presented in Table 7. The abundance of toxic species may be included in a criterion of condition and in the sites examined in this investigation the genera which attained important properties were (i) Cheilanthes on laterites and (ii) Solanum, Portulaca and Threlkeldia on cracking clays.

Table 7 : Genera of western Queensland plants which include species known to be toxic to stock

Trachymene (T. ochracea)	Euphorbia (E. drummondii)
Tribulus (T. terrestris)	**Phyllanthus**
Zygophyllum (Z. spp.)	Senecio
Cheilanthes (C.sieberi)	Xanthium (X. pungens)
Nicotiana (N. glauca)	Cucumis (C. myriocarpus)
Solanum (S. spp.)	Threlkeldia (T. proceriflora)
Pimelea (P. spp.)	Trianthema (T. triquetra)
Oxalis	Sarcostemma (S. australe)
Portulaca (P.sp.aff.**P. oleracea**)	Indigofera
Eremophila (E. spp.)	Crotalaria (C. spp.)
Isotropis	Cassia (C. spp.)
Swainsona (S. spp.)	Goodenia

(12) The perennial plants capable of constituting a relatively stable ground cover are known and are indicated in the tables.

(13) The combinations of ground layer plants which are likely to yield the highest sustained animal production have been drawn up and listed as key species for each major soil type. In the mulga country, the important additional factor of topfeed complicates this aspect of condition assessment. It will be necessary in drawing up criteria and standards for condition assessment in mulga country to decide an optimum density of topfeed above and below which condition values decrease (See Section A. 3 (d)).

(14) Whether the desired combination of plants coincides with the "climax" vegetation appears to vary with soil type. In practical terms, the answer to this question is not always important, provided the most productive botanical composition (sere, stage, species combination) can be recognized and management procedures conducive to its maintenance or development are known. Briefly, it appears that the mulga country often develops beyond the most useful stage while in the Mitchell grass country this danger apparently does not exist, in terms of botanical composition. However, in terms of projected canopy cover it may be that a full Mitchell grass canopy does in fact go beyond the most productive stage.

The basic questions of which species are the desirable (key) species and how far is the present vegetation removed from the "potentially best" vegetation can thus be only partially answered at this stage. However, even when more comprehensive survey and laboratory data are available, condition assessment would not necessarily be practicable in western Queensland. Wherever condition assessment is applied, certain formulation problems arise, concerned with the choice of condition criteria, the intensity of sampling required for assessment, the scales of values to be used in a condition score sheet and the differential weighting of criteria. These problems are procedural details which need to be decided upon in the knowledge of local vegetation and soils.

The decisions made on the above details are important but are not basic to the overall acceptance or rejection of the central philosophy on which condition assessment is based? The two fundamental questions which must be answered are:
(a) Does the vegetation exhibit a predictable successional pattern of development? and
(b) Can the stages (seres) of development (succession) and degradation (retrogression) be identified on a botanical basis.
If a predictable sequence of dominants is not part of the dynamics of the vegetation concerned, then the stage or position of any current botanical composition cannot be determined. This in itself is not important, but in such an unstructured vegetation neither the effect of grazing nor that of spelling could be determined or predicted. Thus, although condition in the immediate context can be gauged from current botanical composition, unless the present symptoms can be

used to infer past treatment influences and to halt or modify these where they have been detrimental, condition assessments have no meaningful application. In this sense, the present study is a parallel to the early medical research, in which the terms of reference were "to investigate the possibilities of the application of the concept of human temperature". It was possible to construct a thermometer (condition assessment tool) and it was possible to record the patient's temperature (rating score card) with this tool. However, this procedure is fruitless unless (a) the recorded temperature (assessment) is known to be a symptom (result) of a causal process (seral development) and (b) that this symptom can guide in decision-making (management) in remedying (manipulating) the patient's (resource's) ill health.

Circumstantial evidence on the existence of successional patterns in western Queensland does not facilitate the problem, already referred to, of identifying and separating the causal roles of both management and climatic fluctuations. The ability to isolate management effects on botanical composition and cover is necessary if the advantages and disadvantages of differential stocking rates, seasons of grazing and types of animals are to be exposed by ecological measurements of the resultant vegetation. Similarly, the accuracy with which the effects of animal manipulation options on future vegetation trends can be predicted will be very low unless climatic contributing effects can be distinguished from management effects.

E. SEMI-ARID PASTURE MANAGEMENT IN AUSTRALIA - NEEDS AND POSSIBILITIES

1. Introduction

The need for a more serious consideration of management possibilities is exposed by the foregoing review of the state of much of Australia's semi-arid grazing lands. While no Australian philosophy on semi-arid pasture management has been developed and no systems widely recommended as in other similar situations in the world, many local workers have generalized on the need for some type of maintenance/reclamation procedure to preserve the production potential of these areas.

The overview which follows aims to consider the following facets of vegetation utilization:

(a) evolutionary aspects of the vegetation,
(b) changes due to grazing,
(c) carrying capacity,
(d) needs for, and aims of, grazing management,
(e) establishment of basic principles of management,
(f) results from experimental grazing systems, and
(g) practical recommendations on property management.

In reviewing the present status of knowledge on world ecosystems, Odum (1962) concludes that grazing is one of the most important practical problems facing mankind; yet little is known about the actual situation in natural ecosystems: "Well-ordered and stable ecosystems seem to have numerous mechanisms which prevent excessive grazing of the living plants. Sometimes, predators appear to provide the chief regulation; sometimes weather or life history characteristics (limited generation time or limited number of generations of herbivores) appear to exercise control. Unfortunately, man with his cattle, sheep and goats often fails to provide such regulation with the result that overgrazing and declining productivity is apparent in large areas of the world, especially in grasslands".

"While introduced grasses and legumes are useful in the better rainfall zones only a limited number is showing any promise where rainfall is scanty. This being the case, we should judiciously stock our native species to maintain the present populations and also to encourage them to spread; it would be a national calamity if the native grasses, many of which nature has endowed with drought resistant capabilities, disappeared from our low rainfall zones, because there are no introduced grasses which could entirely replace them". (Anon, 1956).

Beadle's (1948) classic work on the natural pastures of western New South Wales emphasizes the extent of deterioration and the need for vegetation management in semi-arid areas: "The solution to the erosion problem in our dry grazing areas requires the maintenance or regeneration of adequate vegetation, particularly perennial vegetation. More recently, Ebersohn (1967) has made a strong case for priority to be given to "cheap methods such as ecological pasture management" in the sheep-producing semi-arid regions of Australia.

In evaluating the possibilities of applying management principles evolved in other countries, to Australia, Perry (1968) points to three differences between Australia's arid rangelands and those of the other countries:

(a) The short history of use by domestic stock in Australia.
(b) The total government ownership of Australia's arid lands.
(c) The lack of opportunity to apply seasonal or nomadic pastoral systems in Australia, due to land tenure, distances and topography.

Unlike certain other semi-arid countries where the herbaceous flora has evolved under intermittent heavy grazing by migratory herbivores (Roberts, 1971), Australian natural pastures in general do not possess an inherent resistance to defoliation (Osborn, 1928). In this regard, Anderson (1941) states, "Some of our grasses, however, notably Danthonia bipartita, Eragrostis eriopoda and Neurachne mitchelliana, have buds which appear to be better protected from grazing by the fact that they are very close to the ground or are situated just below soil level". (Although this opinion needs to be verified, a study of the differential tolerance to grazing of the potentially dominant grasses in the semi-arid pastoral areas should be a high research priority).

Management in the past has been aimed almost solely at attaining maximum animal production often at the expense of the basic pasture resource, the requirements of which have been neglected. Moore (1969) raises a point of prime importance when he states, "The apparent rapid recovery of depleted range after rain (Dorothea Mackellar's 'filmy greenness that thickens while we gaze' B.R.R.) encouraged graziers in the belief that the range could not be permanently damaged, and unfortunately, this view still exists in some quarters". It is the writer's opinion that demonstration of the validity or otherwise of Moore's above statement is urgently required at this stage in the determination of research priorities in pastoral Australia. It appears that the inconspicuous, and often slow, change in botanical composition is not always observed by producers or animal-orientated advisers. This situation has led Moore (1969) to claim that the drier areas of Australia have been "largely neglected by ecologists, and graziers have had little guidance in the development of sound management practices".

In this regard, the time factor is of great importance since both natural sources of seed of good fodder plants and fertility are becoming less favourable with time. In certain areas the stage has been reached where, as Williams (1968) has shown, exclusion of stock gives no positive reaction in the absence of desirable species suitable for colonization of degraded sites.

In an outline of management options for the pastoral zones, Williams (1970) asks, "Will grazing by sheep at this time, or some other time at a particular stocking intensity, cause deterioration, or lead to improvement in the pasture components of most value?" Williams assumes that perennial forage plants are essential in carrying breeding animals from one period of rainfall to the next and continues as follows: "Most pastures that have been heavily utilized will have lost, or have a reduced number of, plants of species susceptible to severe grazing pressure. Further, there may have been an increase in the number of plants of species tolerant to the range of poor grazing regimes, or unacceptable to the herbivore. The first type of species are 'decreasers' and the second type are 'increasers'. Ultimately succession will proceed to the disclimax stage where grazing manipulations produce no worthwhile effect in floristic terms. The plant species remaining in such a pasture are those which have survived many previous droughts and concurrent severe grazing by sheep to a point where the sheep died. However, if succession (retrogression? B.R.R.) has not proceeded far, it is possible that deferment routines could lead to enhanced pasture production and to more stable animal production. New procedures, added to those which produced a particular assemblage of plants, may lead to further change, but in a new direction, e.g. rapid de-stocking and re-stocking, deferred or rotational grazing, grain feeding, fertilizer application".

Perry (1972) has recently re-emphasized that basically the influence of grazing on rangeland ecosystems is determined by three main factors:

(i) intensity of stocking,
(ii) distribution of stock, and
(iii) season of use.

Perry maintains that although deterioration of natural pasture in Australia is often equated with overstocking, in many cases the damage has probably been caused by poor distribution of stock, or grazing at the "wrong season", rather than by too many stock. According to Perry (1962) it is known that grazing during drought, when the fodder plants are dormant, has little effect on most perennial grasses, but that they are "readily damaged during the early growing period". This general principle has long been accepted in North America (Laycock, 1967) and South Africa (Roberts, 1965).

To attain stability, and thus maintain long term production from any ecosystem, it is necessary that the animal biomass be in equilibrium with plant production. In some ecosystems, the biomass of wildlife which can safely be supported contrasts sharply with the biomass of domestic stock carried, as shown by Sharkey (1970). The evidence (Beadle, 1960) indicates that the semi-arid vegetation of Australia evolved under relatively light use by grazing animals, except near permanent water holes. This factor, in conjunction with evidence on natural fires following good seasons in earlier years, should be considered when solutions to the problems of overgrazing and bush encroachment are sought. In this regard, Ebersohn (1970) states, "No evidence is available to substantiate the claim that the vegetation (of Australia's arid zone) has evolved under a migratory use regime, nor have systems of rotational grazing demonstrated any real superiority over free grazing".

Within the semi-arid pastoral ecosystem, the animal is the only factor which lends itself to economical short-term manipulation. This includes the breed, the type of animal, grazing pressure and grazing system (Perry, 1962), which in turn includes season of grazing and length of grazing and spelling periods.

Many stocking rate trials in the southern districts of Australia have shown production and economic returns to increase with increased stocking rate. There is evidence (Anon. 1967 p.8) that, in south-western Queensland, the opposite may hold, and recent studies by Childs (1972) in the black soil area of south western Queensland support this latter evidence.

Perry (1962) states that graziers tend to err on the side of attempting to obtain higher short term production, but that "administrative authorities who view land as a long term resource wisely lean on the side of conservation". This certainly cannot be said of the authorities responsible for the Warrego country, if Heathcote's (1964) graph of official carrying capacity figures and actual stock numbers over the last century are considered.

Griffiths Davies (1955) maintains that the exploitative phase of settlment of the semi-arid areas has been replaced by "a clearer realization of the importance of maintaining the perennial dominants of the association in a vigorous condition, and the rate of stocking has everywhere been markedly reduced, though there is still too heavy a grazing pressure in many instances". This latter opinion is clearly borne out by Ratcliffe (1937), Beadle (1948), and Chippendale (1963). Griffiths Davies (1955) points out that while over-grazing is harmful, moderate grazing may improve the vigour of certain semi-arid pastures, as demonstrated by Osborn, Wood and Paltridge (1932) in the saltbush country of N.S.W. Improvement of pastures as a result of stocking is also recorded by Ebersohn (1967) who postulates that in the Mitchell grass area stocking may have a beneficial effect on the moisture relations of cracking clays.

2. Western Queensland:

The importance of pasture maintenance in south-western Queensland is clearly recognized in some circles, as evidenced by the recent statements of Ebersohn and Lee (1972): "The necessity to ensure the continuing welfare of the native grazing lands is accepted as self-evident......Their sustained productivity commensurate with physical resource:biotic environment equilibrium is an ever present challenge......"

While not advocating any rotational or spelling treatment in grazing management of western Queensland, Everist (1967) considers that the maintenance and improvement of important plant species requires:

(i) conservative grazing during "normal seasons" (based on a rainfall expectancy considerably less than the arithmetical average),

(ii) the removal of animals during major droughts, and

(iii) avoidance of restocking during the first few weeks of plant growth following drought-breaking rains at which time pasture species are at their most vulnerable stage.

Entwistle (1970) states that, "Continuity of production from Australia's rangelands depends upon the conservation of the plant community, or the manipulation of the (existing) community to form a more desirable community. Development is thus a matter of obtaining full utilization of the pastures by ensuring they are available to the grazing animals and that they can be protected periodically from grazing". Apart from periodic protection from grazing, the intensity of defoliation is important, and of the various grazing manipulations available, the American "take half, leave half" approach, in the opinion of Ebersohn (1970), incorporates at least some features of sound grazing management.

Everist and Moule (1952), while stressing the primary control which climate exerts on western Queensland's pastures, point to the possible role of management within this variable environment: "While semi-arid Queensland has always been subject to periodic droughts, the introduction of domestic animals, restricted to circumscribed areas, brought an important new factor into the ecology of the region. In some cases this biotic factor has been decisive in inducing drought conditions". These authors make an unusual statement on the desirability of reducing plant density:"The density of plant cover can be modified to some extent by grazing, mowing and burning. In seasons with very wet summer months the soil is soaked to a considerable depth, and a very luxuriant growth of grasses and other plants results. The increase in plant density brings about increased transpiration and therefore an increased rate of removal of soil moisture. Some of the moisture in the subsoil can be conserved by reducing the plant cover, either by grazing or by mowing. In extreme cases, burning may also be used, but the deleterious effects of fire may be serious enough to offset its advantages. Whatever means are employed to reduce the density of the plant cover, the effect is to decrease the rate of removal of water from the soil and thus allow the pasture to remain in good condition for a longer period. If the removal of leaf is too drastic, the plants may die due to exhaustion of their food reserves, so in applying this practice, judgement based on appreciation of the principles involved is needed."

In south-western Queensland management aimed at maintaining optimum tree density is of particular importance. Beale (1971) has attempted to develop the perspective required to translate tree density and productivity data into generalized management recommendations. As has been shown in other parts of the world, Beale's study supported the finding that even relatively low tree populations (below 40 trees/ha) have a very significant influence on ground cover production.

Burrows and Beale (1969) maintain that while future short term recordings of permanent transects in the semi-arid mulgalands of western Queensland are not expected to reflect marked changes in perennial species composition, the densities of the more palatable (woody) species could fluctuate markedly and would depend on climatic conditions, grazing pressure and management.

It is not necessary to reiterate the role of topfeed in the drier areas of pastoral Australia, as has been stressed by countless local writers. What is necessary to stress, is the central position of grasses in the diet of animals, even in the driest regions. Chippendale (1965a) has accumulated quantitative data to demonstrate that even in Central Australia, in wet and dry times, "75% or more of the plants eaten (by cattle) are grasses". This proportion rises to 100% after good rains, while non-grass herbage is usually less than 10% of the diet, although the herbage and topfeed are important in supplying nutrients which grasses are deficient in. Chippendale's (1964) original report showed that topfeed rarely made up 20% of the plants eaten, and usually less than 10%.

Mitchell grass management is rather different from that of most other semi-arid areas in that Mitchell grass country is (a) virtually treeless and generally free from timber problems, except in marginal Gidyea areas, and
(b) it is usually completely dominated by Astrebla species.
What little has been written on maintenance and management of Mitchell grass in western Queensland is summarized below.

Because subdivision of properties into vegetation units is usually not practical (Roe and Allen 1945) and because of the nature of the rainfall, improper use of Mitchell grass on properties having other types of pasture is to be expected. Means of reconstituting such pastures is therefore desirable.

Seedling regeneration following reasonable seasonal rainfall will be largely dependent on the seed reserve present in the soil at the time of the rain. It is not unreasonable to expect that such seed reserves would be low. In a depleted pasture most regeneration in Mitchell grass, in the first year at least, would be expected from vegetative growth. Such vegetative growth would be expected to increase seed supplies given satisfactory rainfall and pasture spelling to allow maturation of seed.

For slightly deteriorated pastures such a method should be satisfactory. For severely deteriorated pastures in which the seed source has been depleted, a longer term programme would be essential for full pasture reconstitution because of the impracticability of artificial reseeding.

A programme of strategic pasture spelling as part of continuous vegetation management may ensure that at most times a satisfactory reserve seed supply exists in the soil. With reasonable seed reserves in the soil pasture vigour should be maintained even in years when rainfall is slightly below average.

Vegetative regeneration of Mitchell grass is initially dependent upon carbohydrate reserves of the root stock. If a root stock is subjected to continual overgrazing for a number of years the carbohydrate reserves would be low. This would, of necessity, involve spelling of the pasture for the duration of active growth during the first year.

The regeneration of degraded Mitchell grass pastures is therefore dependent upon at least occasional spelling for at least a full active growth period. From observations, many Mitchell grass tussocks, apparently dead, are capable of regenerating, given satisfactory soil moisture and unimpeded growth (Everist, personal communication). During this phase of active growth, seedling establishment can also occur. Thus, in a single short period of pasture spelling a return to a more stable pasture can be obtained. For severely degraded pastures, however, spelling during active growth over a number of seasons may be necessary.

It is,therefore, necessary for the pastoralist to recognise pasture deterioration early in order to avoid the need for long recovery periods. Throughout the literature, there is a notable lack of information on the effects of fire, soil erosion and carrying capacities in Mitchell grass country. Weston (1963) reports that many Mitchell grass pastures subjected to fire have developed into *Aristida latifolia* (Feather top wire grass) areas. He maintains that Mitchell grass appears most susceptible to fire, particularly when a large bulk of dry matter is present. However, Purcell and Lee (1970) reported that the population of *Astrebla* was stable during fire treatment applied over five years, aimed at elimination of *A. latifolia*. Of importance in this instance is the fact that for the duration of this trial rainfall was well below average. Entwistle (personal communication) maintains that cool fire, as would occur in low rainfall years was not damaging to Mitchell grass, while in years of good rainfall the resultant hot fire would cause damage to Mitchell grass.

The scarcity of information available on the effects of erosion may reflect the overall stability of Mitchell grass pastures. While pedestalling of old tussocks is noticeable on badly degraded pasture, it appears that erosion losses on more stable pastures are small.

The lack of information on carrying capacities is significant and is probably related to the inherent variability of the rainfall. The problem of establishing the carrying capacity of Mitchell grass pastures is summarised by Holland and Moore (1962): "If stock numbers are regulated to a series of favourable seasons their maintenance on pastures through a drought is either not possible or puts such pressure on the native pastures that severe overgrazing and stock losses result. If stock numbers are such that maintenance through a drought is possible, only a small proportion of the pasture growth is utilized in favourable seasons". Under the circumstances stocking rate should be seen rather as a variable range, than as a set number, and unless feeding programmes are resorted to, some degree of variation in animal numbers to meet seasonal fluctuations in fodder production is indicated.

3.General Aims:

Noting the similarities in the forms of deterioration which have taken place in arid areas all over the world, Moore (1959) has concluded, "The problem of management, therefore, in many arid areas may be essentially one of maintaining a favourable balance in the proportion of palatable and unpalatable species".

Moore (1969) puts the essentials of arid zone management in the following terms: "....The principal objective of management must be to maintain or re-establish conditions suitable for the regeneration and survival of useful species, so as to permit continued utilization and to prevent erosion. Management systems with such objectives undoubtedly mean under-utilization at particular times and season of the year".

Without suggesting the physical improvements or manipulation particulars of how management should be applied, Chippendale (1968) maintains that, as in New South Wales (Leigh and Mulham, 1966), proper management of arid Central Australian pastures, would aim to "utilize the annual species, particularly while fresh, but not to overgraze the perennial species". Chippendale (1968) based this conclusion on quantitative diet studies which demonstrated that both these groups of plants played an important role in cattle nutrition.

Perry (1962) maintains that the dual objectives of range management, namely production and conservation, are incompatible and that the basis of management should be a compromise. This supposed incompatibility reflects what may have been a basic fallacy in Australian evaluation of grazing systems (rotational or deferred) as applied to natural pastures. Unless a grazing system was able to give a higher yield of animal products than set stocking did over the relatively short experimental periods employed, they were deemed to have "no advantage". This assessment is only partial as it does not consider the central aspect of stability and long term productivity maintenance, as shown in South African comparative trials, when continuous grazing gave good results for the first 15 years of the experiment, then entered a period of progressive collapse.

4. Development of Principles:

In analysing the factors of importance in the management of natural pastures, Davies (1946) was one of the first to identify the need for research on the basis of vegetation maintenance. The two factors considered to be of greatest importance in grazing management were:

"(1) deferment of grazing at critical stages, for example, after opening seasonal rains or at seeding, and

(2) the adjustment of the rate of stocking to the optimal level for the vigorous survival of the important fodder species" (Griffiths Davies, 1946).

It was stated at that time, that it was not continuous grazing as such, that was the principal factor in the overgrazing and weakening of desired species, but the temporary or continuous overstocking of the pastures. Evidence supporting this opinion was published by Roe and Allen in 1945, based on their research in semi-arid Queensland. Davies (1946) states,"The remedy (in cases of overgrazed land) is to be sought along the lines of adjusting the grazing pressure at the critical growth stages of the important component species; or the reduction of grazing pressure over a number of seasons and perhaps permanently".

In applying deferred grazing, stock would have to be withheld from a certain area during critical stages for one or more seasons and would be allowed "temporarily to overgraze other areas" (Davies, 1946). It was recognized that the critical grazing pressure (both the degree and the time) would vary between the different types of natural pasture on large properties. The Mitchell grass, mulga and ironbark associations of semi-arid Queensland are quoted as examples of such distinctive types (Roe and Allen, 1945). The response of these associations to the same rainfall was recognized as being quite different. Although controlled grazing of the various associations according to their critical growth stages was being applied to some extent in practice, the immediate welfare of the stock, rather than the less obvious benefits to the pasture's long term productivity, was the main determinant in stock movement.

While Davies (1946) emphasized that the success of deferred grazing in Australia "still remains obscure", the need for paddocks was accepted: "The subdivision of a grazing property so that the different pasture associations are separately fenced would therefore appear to be the best approach to control of the grazing animal, rather than attempt to divide for rotational grazing" ("Rotational grazing" was distinguished from "deferred grazing", the latter being a "changing of the rate of stocking during part of the growing season" - B.R.R.).

Within the unpredictable environment of semi-arid Australia, range management needs to be flexible so that it can be adapted to the ever-changing ecological situation. The required management must be applicable to the place and time concerned, and a knowledge of present and past treatment are required (Perry, 1962). For this purpose the condition and trend of the ecosystem needs to be assessed.

5. Systems:

It is claimed that "virtually no work" has been done in Australia on the effects of range management practices such as "spelling, rotation, seasonal grazing and periodic intensive grazing" (Newman, 1971). It is further maintained that, "There is little practical evidence that production advantage will accrue from specialized grazing systems as compared to set stocking patterns" (Newman, 1971). At the same time, however, there is considerable evidence that pastures can be modified by grazing at particular times and by spelling as shown by Leigh and Mulham (1966). At present the possible usefulness of grazing systems may be in (i) developing special purpose pastures, (ii) in encouraging and discouraging particular types of plants and (iii) in reclaiming overgrazed areas (Newman, 1971).

Myers (1972) has recently reviewed the effects of various grazing systems on Australian pastures in general. As with his predecessors in management reviewing (Wheeler, 1960; Arnold, 1969; and Willoughby, 1970), Myers finds little evidence to justify the capital and labour required to practice rotational rather than continuous grazing. In similar vein, Goodall (1970) estimates that in the semi-arid situation, subdivision and rotational grazing would yield only small advantages. Over a wide range of pasture types and environments, the evidence suggests that systems of management, other than continuous grazing, are unlikely to increase gains. Myers states flatly, "No experiment to date (1970) has established that rotational grazing of a pasture leads to really substantial gains in animal production."

It should be stressed that animal production, over the short term that the majority of Australian grazing experiments were conducted, cannot be construed as the most meaningful criterion of success of management systems applied to semi-arid vegetation. The only grazing management in south western Queensland is that of Roe and Allen (1945), which suggested that there were no significant differences in production between rotational and continuous grazing.

After reviewing all the reported Australian research on pasture management, Willoughby (1970) concludes, "On present evidence, lucerne excepted, the only surety attached to the adoption of most grazing management practices is the extra cost they incur. The possibility of greater returns from the management of conventional grassland communities remains in doubt". Willoughby (1970) makes a number of basic points in analysing the possible reasons for the results obtained in grazing experiments: "Firstly, continuous grazing is a practicable system of grassland utilization and is capable of high animal production. Secondly, any other system of pasture management requires that the stock be restricted for a time to less than the whole food supply available and thus introduces the risk of current animal production being depressed. For a management system to be superior to continuous grazing, subsequent access to the previously protected area must more than compensate for this prior depression. Favourable years and low stocking rates increase the amount and duration of feed surplus, so that there is minimal depression of animal production during the period of restricted grazing. But these conditions also lead to minimal increase in animal production during the subsequent period of use of the protected area, so that the total effect of the management treatment on annual animal production is small. The less favourable the year or the higher the stocking rate, the greater and more prolonged are the feed deficiencies; the depression in animal production during the period of restriction is aggravated and pasture growth on the protected area may not be sufficient to make up for this loss. These conclusions are in keeping with the concept that all the grasslands within a property are a feed supply which is augmented by plant growth and depleted by breakdown and intake. To increase the supply, either growth must be increased or breakdown or intake must be decreased. For a given grassland community, the only one of these aspects that can be directly manipulated by management, is to decrease intake and this can be achieved by restricting grazing to only a part of the grassland. Thus a reduced intake with its associated risk of lower current animal production is a necessary preliminary to increasing feed supply by management. A high level of feed available in turn may mean a high level of breakdown. The levels of all these factors determine whether final animal production is reduced, unchanged, or increased by management procedure."

Experience with the apparently fragile range ecosystem of semi-arid South Australia has led Lange (1972) to take a pessimistic but possibly realistic view of management possibilities in the drier areas. Lange points out that, while the official policy (Anon. 1936) aims to stock the arid lands and to perpetuate their carrying capacity, this may not be ecologically possible: "Some may seek stability via understanding of animal and plant behaviour, with ideas of deferal, spelling or rotation in mind. Here the problem is unpredictability of climatic events in the system, of an order quite beyond that encountered in most agriculture. A rotation accommodating droughts of several years' duration is hard to imagine". Lange maintains that there can be no successional change towards "stable, more productive seral grassland" in the arid regions, since in less than the natural lifespan of the major species, the "whole machinery of a potentially productive ecosystem is devastated: flora, fauna, cycles, topsoils and all".

Despite the lack of experimental evidence supporting rotational grazing, certain extension services in Australia actively recommend intensive subdivision and frequent movement of stock while other advisory organizations recommend continuous grazing or set stocking (Willoughby, 1970). In arid Western Australia, Suijdendorp is reported (Mallett, 1955) to have demonstrated the beneficial effects of deferred grazing in spinifex country. The deferred grazing system referred to consists basically of removing the sheep from one quarter or one third of a property at the time of the first rains, sufficiently long (approx. 8 weeks) to allow the fodder plants to mature and set seed. This is followed by heavy stocking. Claims of the "convincing demonstration" of this system on two stations (Abydos and Woodstock in the Port Hedland area) are recorded by Mallett (1955) and Suijdendorp (1955). However, Nunn (1960) has warned that because of more variable rainfall further south, deferred grazing cannot be applied in the same way elsewhere in Western Australia where long term spelling is needed. In the application of Western Australian recommendations on management, the need for more ecologically placed paddock fences on pastoral properties has been stressed by Froome (1971): "Traditionally, any fencing in pastoral areas has been 'on the square' with the fences aligned north-south and east-west. Other than its neatness and ease of construction this system has little to recommend it. Fencing should be planned to separate areas of different vegetation types, to take advantage of available water supplies and to allow control of different categories of stock". Froome suggests that in the mulga zone of Western Australia, vegetation types which should be separated are saltbush, mulga, spinifex, limestone areas and alluvial plains. Such divisions could allow management of each area at a time and stocking rate that will cause least permanent damage to the different vegetation types. In addition, degraded areas can be more easily regenerated and stocking rates can be adjusted to the present carrying capacity of the property as a whole (Froome, 1971).

In many cases, the condition of stock is not a reliable indication of the condition of natural pasture. Suijdendorp's (1955) experience at Woodstock station (N.W.-W.A.) was that, "while they are wrecking the vegetation, the stock are apt to remain in good condition as they keep the grasses eaten down during the growing season and are subsisting on young, highly nutritious shoots coming up over an extended period".

6. Potential for ecologically based management in western Queensland

The overriding influence and control which unpredictable climate has over the growth and production of pastures in western Queensland has led many workers to believe that management can be no more than peripheral in the production system of this region. In view of the evidence of deterioration of the natural resources it is worth re-examining the possibilities of ecologically based management.

Grazing land management is both the art and the science of planning and executing the use of vegetation so as to attain the highest livestock production consistent with conservation of the natural resources. This implies skilful manipulation of those factors subject to control by the manager. In western Queensland the following variable factors may be used in developing management strategies to meet the demands of different seasons, different types of grazing land, different condition of paddocks and varying economic demand and costs:

Breeds of livestock
Ratio of sheep to cattle
Total number of livestock
Strategic alteration of numbers of each class of stock
Combination of animal groups
Fencing of separate vegetation types
Spelling of paddocks
Heavy intermittent grazing of paddocks
Positioning of watering places and licks
Burning
Mechanical shrub control
Water spreading
Seeding to sown pasture

These controllable factors provide the basis for alternative management strategies within an environment characterized by the following facts:

(i) The varied nature of the vegetation and the position of water, results in overgrazing of certain portions of paddocks and under-utilization of other portions.

(ii) Nutritious perennial grasses and herbs decrease and disappear in the absence of opportunities to seed and establish.

(iii) Unpalatable species increase and dominate when competition from other plants is eliminated by over-use of the latter.

(iv) Mulga regeneration is dependent on the absence of sheep grazing after germination.

(v) Control of mulga is necessary if this species of topfeed is to be kept at a useful height and at a density which does not eliminate the grass cover.

(vi) Mitchell grass is replaced by annual weeds if overutilized.

(vii) Woody weeds increase in the absence of competition from grass and the elimination of fire.

Theoretically the following aspects of management may be applied to reduce or negate the above detrimental processes:

(i) By more uniform distribution of water and by the fencing off of different vegetation types, where these are of an economical size, better use of the grazing as a whole can be expected.

(ii) By fencing of different types of grazing into separate paddocks, each vegetation type can be stocked according to its present carrying capacity and managed according to its particular requirements.

(iii) By adjusting total stock numbers in such a way that certain paddocks are spelled each growing season, the more valuable perennial grasses may be encouraged and increased. In many cases spelling should be long enough to ensure seeding and establishment of nutritious perennials in those paddocks most in need of such improvement.

(iv) Dominance of less palatable grasses may be counteracted by intermittent grazing for shorter periods rather than by continuous grazing.

(v) Mulga regeneration may be encouraged by the use of only cattle for a sufficient period to ensure mulga establishment. During this period those grasses most palatable to sheep would also be encouraged while the coarser grasses would be relatively well utilized.

(vi) Once sufficient mulga regeneration has been obtained, the topfeed may be maintained in a useful state for sheep by strategic heavy grazing with cattle or sheep depending on the size and density of the young mulga.

The choice between grazing during summer or winter may be important in this case. It may be expected that grazing with sheep during winter would have a much more beneficial effect on the grass, than would summer sheep grazing. Sheep would also be expected to have a more advantageous pruning effect on the mulga during winter, than during summer when the grass would often be green. On paddocks in poor condition, grazing during the summer by cattle or sheep would be more detrimental than winter grazing.

(vii) The combination of certain herds or flocks during certain seasons may allow for heavy intermittent grazing of certain or all paddocks if required to utilize a bulk of coarse feed or prune top-feed back.

Clearly two basic requirements must be met before sound vegetation management becomes practicable:

(a) property size (Ebersohn, 1970) must be large enough to generate a reasonable income without having to heavily graze all paddocks continuously, and

(b) stock numbers must be realistic for the productive capacity of the area concerned.

Increased profit per acre from a lower number of animals may be a very real issue in certain cases and has been demonstrated in practice by several land-holders. Under the variable climate prevailing, optimum stocking rate can never be constant and the removal or addition of a proportion of total stock numbers, in the form of wethers, may thus be accepted as a facet of efficient management.

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F. OVERALL RESEARCH NEEDS AND THE FUTURE OF THE DRIER AREAS

This study has examined both the evidence of deterioration of Australia's semi-arid pastures and the published contributions on management possibilities of these resources. The need for a comprehensive and meaningful research programme in the areas concerned is emphasized by both the extent of deterioration and the lack of locally developed management principles.

"Considering the economic importance of Australia's arid pastures, they have been the subject of very little past research. This has been due largely to their very low human population and the lack of awareness by Australia's largely urban population of the importance of the rangeland industries and their research needs" (Perry, 1968). Perry (1967) has given a detailed overview of the need for rangelands research in Australia, in an area comprising 74% of the continent and producing export earnings worth approximately $450 million annually. The approach envisaged will require a knowledge of both condition of the pastoral resources and their reaction to management. Perry's factually-based challenge merits the serious attention of research planners at the highest level in Australia.

In Perry's (1968) words, "The object of range research is to understand the (eco-) system well enough to be able to design management practices which will keep it in equilibrium." The need for a more serious attempt by Australian research workers to understand their natural grazing ecosystems was highlighted by the Armidale Soil Conservation Colloquim (Costin, 1967) which formulated the following recommendation: "That investigations over a wide range of environments be undertaken to determine (a) the species of plants eaten in different seasons by particular species of animals,

(b) effects of different degrees of defoliation of grazed species at different stages in their development,

(c) indicator species of pasture condition and trend,

(d) relative importance of changes in vegetation induced by climatic fluctuations and grazing,

and (e) significance, in terms of plant and animal productivity, of soil (and fertility) erosion in the arid and semi-arid zones."

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Also the earlier plea by Hall, Specht and Eardley (1964) for more autecological studies on herbage species on which animal production in the drier areas is based, bears repeating. Australian scientists would benefit from Cook's (1969) suggestions.

It has long been recognized that the pattern of natural vegetation can be used as a sensitive indicator of environmental differences. Daubenmire (1968) has used plant cover as a means of classifying landscapes into units of equivalent biological potential. Attempts to quantify predictions of agricultural potential made from well-preserved vegetation have recently shown promise, and in Queensland the work of Webb, Tracey, Williams and Lance (1971) suggests that "if calibration-sites are available, site potential can be assessed accurately from the "intact" floristic vectors alone....... There seems no doubt that, at least in eastern Australia, the potential value of a site for any given agricultural purpose can be estimated from a study of the intact vegetation".

In the study of vegetation changes, most work on plant succession has been entirely of the classic descriptive, often Clementsian, type. It is significant that leaders in Australian quantitative ecology (Williams, Lance, Webb, Tracey and Dale, 1969) have recently initiated numerical analyses of succession phenomena and have attempted to place this sphere of formerly vague generalizations on an objective basis.

Similarly, Tracey (1968) has demonstrated how numerical classificatory techniques can be used to define the heterogeneity of pasture sites and to establish whether differences in botanical composition are primarily due to treatment or site influences. These new analytical tools should be made full use of by researchers in the complex field of management in dynamic vegetation. Attempts to quantify management strategies and their influence on vegetation and then to isolate these influences from climatic effects should allow the verification of assumptions such as, "Range condition reflects past management....." (Anon, 1970), on which Australian vegetation management can be developed.

With the present interest in systems analysis and modelling, Williams (1963) has indicated the possible role of studies of energy flow and nutrient cycling in natural pasture ecosystems, in which sheep and cattle are the selected primary producers. Provided modelling does not become an end in itself these studies may hold considerable promise in gaining a better understanding of the production resources. Perusal of the literature emanating from the regions concerned certainly confirms the criticism by Christian and Perry (1969) that research in the arid region of Australia has lacked the co-ordination and comprehensive approach that the region deserves. Modelling on a regional scale may nullify this serious shortcoming. The writer (Roberts, 1972) has recently summed up the required research programme in the mulga zone in the following four central questions:

1. What physiognomy and floristic composition is likely to yield the best long term production from each type of mulga land?
2. What manipulation, if any, is required to develop and maintain this desired state?
3. What combination of type and number of animals can be safely used in the ecosystem envisaged?
4. What size of holdings is required to achieve ecological and economic feasibility for such production systems?

In conclusion, since maintenance of the natural resources is unlikely to occur, unless settlement policy and fiscal policy encourage ecologically based management, two important studies relating to overall government policy should be mentioned. For any serious student of the pastoral situation in semi-arid Queensland, Heathcote's (1964) precis of his comprehensive search for the facts on pastoral occupation in this area, is basic reading. One of the significant findings of Heathcote's study was the "surprisingly large turnover" of landholders in the Warrego Country since earliest settlement. Comparing the records for the names of landholders at any date with the names which appeared ten years later, indicated that half the originals would have disappeared; a check twenty years later revealed that two-thirds had disappeared. "The lessee who would stay on the plains has been a rare bird; the bulk of his neighbours would have been birds of passage" (Heathcote, 1964).

This impermanence of the pastoral population, together with a fiscal policy which did nothing to encourage the maintenance of natural resources must surely have had a retarding effect on possible development of a long-term conservation approach to pastoral production in this area.

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Heathcote's central question, "Conservation or Opportune Use?" must be a major consideration of all policy-makers concerned with formulating a basis for land use in western Queensland. His graph of sheep numbers for the Maranoa and Warrego districts from 1884 indicate that, although wool per sheep has increased from 5 to 8½lb per head during the 100 years ending 1960, the yield of wool per unit area may even show a loss over this period. This loss would be the direct result of reduced carrying capacity. "Basically neither the increase in stock densities nor the yield per unit area, whether in stock or wool, has met the hopes of official policies and the semi-arid plains remain an area where the returns from resource use are still far below the optima originally set." Heathcote (1964) also points out that the relatively recently (1947) established soil conservation services in Queensland have not been concerned with problems on the semi-arid plains.

"The acceptance of leasehold tenure as a concession to circumstances has not affected the general policy of unlimited intensification of occupation and use. Such a policy, however, needs a relatively stable inventory of resources and a potentially high yield per unit area. Neither of the prerequisites is to be found on the (semi-arid) plains and the results are to be seen in the limited success of official settlement policies. The success which has been achieved, indeed, appears to have been in part the result of illegal occupation and in spite of, rather than because of, official policies" (Heathcote, 1964). The success of settlement, although it has been limited, seems to have been based rather on "opportune use" (heavy stocking in good seasons) than on judicious conservation of the very variable pasture resources of this region (Heathcote, 1964). In similar vein to Heathcote, Ratcliffe (1938 p.329) has been critical of the unrealistic optimism reflected in official policy concerning the carrying capacity of semi-arid Queensland.

No evaluation of the position of pasture deterioration in Australia is complete without serious consideration of the contributions of Ratcliffe (1938) to this subject. His well-known writings on the erosion problems of the semi-arid regions refer to these areas as "nothing less than a battlefield, on which man is engaged in a struggle with the remorseless forces of drought, erosion and drift." Ratcliffe then poses the questions, "Must man in the end be routed and forced to abandon the territory he has seized?

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Will history merely repeat itself? The same battle has been fought before, many times and in many lands - in Africa, Arabia, Asia, America - and man in the end has always suffered defeat, as ruined cities in the desert bear witness today. Cannot Australians, with all the forces of twentieth century science at their command, do better than the ancient races who struggled for the most part blindly and in ignorance?"

It is hoped that this study contributes something to the development of an "early warning system" for western Queensland.

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APPENDIX A

SITE DESCRIPTIONS AND SURVEY RESULTS FROM 36 PRESERVED AREAS IN WESTERN QUEENSLAND

For details of survey technique see "Criteria and technique" section of report.

Taxonomic notes: In September, 1972, a number of name changes were proposed by the Queensland Herbarium. Two name changes affect this survey, namely:
Danthonia bipartita becomes *Monachather paradoxa*
Neurachne mitchelliana becomes *Thyridolepis mitchelliana*.

Site No.1.

Botanical Composition (%):

Aristida contorta	20.6
Goodenia lunata	9.4
Fimbristylis dichotoma	9.0
Themeda australis	8.2
Danthonia bipartita	8.2
Eremophila gilesii	7.8
Tripogon loliiformis	6.4
Aristida jerichoensis	5.4
Digitaria brownei	5.0
Minuria integerrima	3.8
Digitaria ammophila	3.2
Euphorbia drummondii	3.2
Dichanthium sericeum	1.8
Eriachne helmsii	1.6
Enneapogon polyphyllus	1.6
Eragrostis eriopoda	1.0
Cheilanthes sieberi	0.8
Aristida sp.	0.4
Bassia convexula	0.2
Panicum whitei	0.2
Neurachne mitchelliana	0.2
Panicum decompositum	0.2
Dactyloctenium radulans	0.2
Eragrostis lacunaria	0.2
Acacia aneura	0.2
Kochia (K. brevifolia ?)	0.2
Chenopodium rhadinostachyum	0.2
Grass seedlings	0.8

No. of species recorded: 27

Basal Cover: 1.7%

Site No. 2.

Botanical Composition (%)

Themeda australis	32.0
Dichanthium sericeum	14.2
Aristida ingrata	12.6
Fimbristylis dichotoma	10.0
Digitaria ammophila	3.4
Helichrysum semiamplexicaule	3.2
Chloris dichanthoides	3.0
Solanum ellipticum	2.6
Goodenia lunata	2.4
Dactyloctenium radulans	2.2
Aristida contorta	1.8
Tripogon loliiformis	1.8
Themeda avenacea	1.4
Sida sp.	1.2
Portulaca sp. aff. P. oleracea	0.8
Indet. herb	0.8
Eragrostis lacunaria	0.6
Glossogyne tenuifolia	0.6
Chloris	0.4
Kochia villosa	0.4
Enneapogon polyphyllus	0.4
Danthonia bipartita	0.4
Panicum decompositum	0.8
Diplachne muelleri	0.4
Aristida sp.	0.4
Indet. herb	0.6
Ptilotus latifolius	0.2
Eremophila gilesii	0.2
Heliotropium tenuifolium	0.2
Chloris acicularis	0.2
Eragrostis elongata	0.2
Acacia aneura	0.2
Grass seedlings	0.4

No. of species recorded: 33

Basal cover: 6.0%

Site No. 3.

Botanical Composition (%)

Bassia ventricosa	17.8
Dactyloctenium radulans	11.8
Chenopodium rhadinostachyum	6.6
Minuria integerrima	5.4
Aristida contorta	5.4
Indet. Sedge	5.2
Goodenia lunata	4.4
Dichanthium sericeum	4.0
Aristida jerichoensis	3.8
Eulalia fulva	3.4
Digitaria ammophila	3.0
Digitaria brownei	2.6
Salsola kali	2.4
Chloris sp.	2.0
Ptilotus sp.	2.0
Themeda australis	2.0
Sida sp.	2.0
Sporobolus actinocladus	2.0
Tripogon loliiformis	1.4
Portulaca sp. aff. P. oleracea	1.4
Danthonia bipartita	1.2
Fimbristylis dichotoma	1.0
Eriachne mucronata	0.8
Eragrostis lacunaria	0.8
Indet. herb	0.8
Chrysopogon fallax	0.6
Enneapogon polyphyllus	0.6
Cheilanthes sieberi	0.6
Acacia aneura	0.4
Panicum whitei	0.4
Glossogyne tenuifolia	0.4
Eriochloa sp.	0.4
Sporobolus caroli	0.4
Chloris scariosa	0.2
Panicum decompositum	0.2
Eragrostis australasica	0.2
Ptilotus murrayi	0.2
Indet. herb	0.4
Eragrostis australasica	0.2
Eragrostis setifolia	0.2
Astrebla sp.	0.2
Eragrostis sp.	0.2

No. of species recorded: 42 Basal Cover: 3.2%

Site No. 4.

Botanical composition (%)

Themeda australis	30.0
Aristida jerichoensis	18.2
Eremophila gilesii	8.6
Aristida contorta	6.8
Dichanthium sericeum	4.0
Kochia sp. (K. brevifolia ?)	3.6
Neurachne mitchelliana	3.2
Minuria integerrima	2.8
Neurachne munroi	2.4
Abutilon sp.	2.4
Digitaria ammophila	2.0
Bassia ventricosa	2.0
Enneapogon polyphyllus	1.6
Evolvulus alsinoides	1.4
Cymbopogon obtectus	1.4
Danthonia bipartita	1.2
Goodenia lunata	1.0
Boerhavia diffusa	1.0
Heliotropium tenuifolium	0.6
Acacia aneura	0.4
Eriachne mucronata	0.4
Ptilotus exaltatus	0.4
Panicum whitei	0.4
Indigofera linifolia	0.2
Kochia villosa	0.2
Indet. herb	0.2
Digitaria brownei	0.2
Kochia sp.	0.2
Grass seedlings	3.0
Herb seedlings	0.2

No. of species recorded: 28

Basal Cover: 2.0%

Site No. 5.

Botanical Composition (%)

Themeda australis	23.0
Themeda avenacea	13.8
Dichanthium sericeum	8.8
Digitaria ammophila	8.6
Eulalia fulva	6.6
Aristida jerichoensis	5.2
Minuria integerrima	5.0
Fimbristylis dichotoma	4.2
Goodenia lunata	3.0
Aristida contorta	3.0
Solanum esuriale	2.6
Brachiaria gilesii	2.2
Bassia calcarata	2.0
Sida sp. (S. fibulifera ?)	1.8
Chloris dichanthoides	1.2
Eragrostis elongata	1.0
Digitaria brownei	0.8
Ptilotus exaltatus	0.8
Kochia villosa	0.8
Evolvulus alsinoides	0.6
Sida sp. (S. cunninghamii ?)	0.4
Eremophila gilesii	0.4
Panicum decompositum	0.4
Enneapogon polyphyllus	0.4
Neurachne mitchelliana	0.4
Cymbopogon obtectus	0.4
Danthonia bipartita	0.4
Astrebla lappacea	0.2
Heliotropium tenuifolium	0.2
Neurachne munroi	0.2
Eragrostis kennedyae	0.2
Tripogon loliiformis	0.2
Grass seedlings	1.2

No. of species recorded: 32

Basal cover: 6.2%

Site No. 6.

Botanical Composition (%)

Eriachne mucronata	34.8
Amphipogon caricinus	17.4
Minuria integerrima	15.6
Neurachne mitchelliana	11.4
Aristida jerichoensis	4.8
Eragrostis eriopoda	3.6
Kochia sp.	3.0
Aristida contorta	2.4
Danthonia bipartita	2.4
Sida sp.	0.8
Solanum esuriale	0.4
Heliotropium tenuifolium	0.4
Enneapogon polyphyllus	0.2
Themeda australis	0.2
Eremophila bowmanii	0.2
Abutilon sp.	0.2
Eremophila latrobei	0.2
Grass seedlings	2.0

No. of species recorded: 17

Basal cover: 2.0%

Site No. 7.

Botanical Composition (%)

Themeda australis	27.4
Dichanthium sericeum	15.6
Aristida contorta	13.8
Eragrostis kennedyae	11.6
Tripogon loliiformis	7.4
Goodenia lunata	4.4
Eragrostis elongata	2.8
Fimbristylis dichotoma	2.4
Evolvulus alsinoides	1.8
Aristida jerichoensis	1.6
Digitaria ammophila	1.2
Alternanthera nodiflora	1.0
Bassia birchii	1.0
Phyllanthus maderaspatensis	1.0
Enneapogon polyphyllus	0.8
Kochia sp.	0.8
Eragrostis dielsii	0.6
Cymbopogon obtectus	0.6
Minuria sp.	0.6
Sporobolus caroli	0.4
Panicum whitei	0.4
Indet. herb	0.8
Boerhavia diffusa	0.4
Chloris pectinata	0.2
Eucalyptus terminalis	0.2
Chloris scariosa	0.2
Minuria integerrima	0.2
Eragrostis eriopoda	0.2
Sida sp.	0.2
Acacia aneura	0.2
Grass seedlings	0.2

No. of species recorded: 30

Basal cover: 3.8%

Site No. 8.

Botanical Composition (%)

Bassia sp. (B. ventricosa?)	24.0
Bassia sp.	16.8
Astrebla pectinata	9.6
Threlkeldia proceriflora	8.2
Goodenia lunata	4.4
Minuria integerrima	4.2
Salsola kali	4.0
Kochia coronata	3.4
Trianthema triquetra	3.0
Enneapogon polyphyllus	2.6
Bassia sp. (B. lanicuspis ?)	2.4
Tripogon loliiformis	1.8
Sida sp.	2.0
Atriplex muelleri	1.8
Digitaria ammophila	0.8
Abutilon sp.	0.8
Dichanthium sericeum	0.8
Cyperus gilesii	0.6
Eriochloa pseudoacrotricha	0.6
Chloris scariosa	0.4
Solanum ellipticum	0.4
Portulaca sp. aff. P. oleracea	0.2
Alternanthera nodiflora	0.2
Indet. herb	0.2
Chloris acicularis	0.2
Cyperus bifax	0.2
Bassia bicornis	0.2
Aristida jerichoensis	0.2
Minuria leptophylla	0.2
Bassia calcarata	0.2
Acacia cambagei	0.2
Eragrostis setifolia	0.2
Atriplex sp. (A. semibaccata ?)	0.2
Aristida contorta	0.2
Evolvulus alsinoides	0.2
Grass seedlings	2.0
Herb seedlings	2.6

No. of species recorded: 35

Basal cover: 0.8%

Site No. 9.

Botanical Composition (%)

Aristida jerichoensis	36.8
Themeda australis	32.6
Aristida contorta	5.8
Neurachne mitchelliana	4.2
Digitaria ammophila	4.0
Danthonia bipartita	3.8
Eriachne mucronata	2.8
Cymbopogon obtectus	2.0
Neurachne munroi	1.0
Eragrostis eriopoda	1.2
Evolvulus alsinoides	0.8
Sida sp.	0.8
Kochia sp.	0.6
Digitaria brownei	0.6
Panicum whitei	0.6
Abutilon sp.	0.4
Euphorbia drummondii	0.2
Boerhavia diffusa	0.2
Solanum ellipticum	0.2
Enneapogon polyphyllus	0.2
Eragrostis kennedyae	0.2
Grass seedlings	1.0

No. of species recorded: 21

Basal cover: 3.8%

Site No. 10.

Botanical Composition (%)

Eriachne mucronata	33.4
Bassia sp. (B. convexula ?)	12.8
Abutilon sp. (A. otocarpum ?)	7.4
Danthonia bipartita	5.8
Kochia sp.	4.6
Ptilotus exaltatus	4.4
Aristida contorta	4.0
Chenopodium rhadinostachyum	3.6
Eragrostis eriopoda	3.4
Evolvulus alsinoides	3.0
Neurachne munroi	3.0
Neurachne mitchelliana	2.2
Amphipogon caricinus	1.8
Digitaria ammophila	1.4
Enneapogon polyphyllus	1.2
Sida fibulifera	0.8
Cyperus sp.	0.8
Aristida jerichoensis	0.6
Bassia sp. (B. lanicuspis ?)	0.6
Acacia aneura	0.6
Euphorbia drummondii	0.6
Brunonia australis	0.4
Digitaria brownei	0.4
Tripogon loliiformis	0.4
Euphorbia sp.	0.2
Panicum decompositum	0.2
Bassia birchii	0.2
Salsola kali	0.2
Heliotropium tenuifolium	0.2
Schizachyrium fragile	0.2
Ixiolaena sp. (I. tomentosa ?)	0.2
Grass seedlings	1.2
Herb seedlings	0.2

No. of species recorded: 31

Basal cover: 1.0%

Site No. 11.

Botanical Composition (%)

Neurachne mitchelliana	25.8
Danthonia bipartita	20.2
Cymbopogon obtectus	12.6
Aristida jerichoensis	10.6
Bassia convexula	5.2
Kochia villosa	5.0
Digitaria ammophila	3.8
Themeda australis	3.4
Rhynchelytrum repens	2.6
Hibiscus sturtii	2.2
Cheilanthes sieberi	0.8
Ptilotus exaltatus	0.8
Salsola kali	0.6
Helichrysum semiamplexicaule	0.6
Tripogon loliiformis	0.6
Enneapogon polyphyllus	0.4
Boerhavia diffusa	0.4
Portulaca sp. aff. P. oleracea	0.4
Panicum decompositum	0.4
Eremophila gilesii	0.4
Convolvulus erubescens	0.2
Digitaria brownei	0.2
Portulaca filifolia	0.2
Tragus australianus	0.2
Eriachne helmsii	0.2
Acacia victoriae	0.2
Trachymene ochracea	0.2
Grass seedlings	1.4
Herb seedlings	0.4

No. of species recorded: 27

Basal cover: 3.6%

Site No. 12.

Botanical Composition (%)

Brachyachne convergens	17.6
Dactyloctenium radulans	11.8
Abutilon malvifolium	10.4
Iseilema membranaceum	9.6
Astrebla pectinata	8.8
Portulaca sp. aff. P. oleracea	8.2
Bassia calcarata	4.2
Astrebla elymoides	3.0
Goodenia sp.	2.8
Solanum esuriale	2.2
Swainsona campylantha	2.0
Bassia bicornis	1.8
Portulaca filifolia	1.8
Eriochloa pseudoacrotricha	1.8
Bassia divaricata	1.6
Hibiscus trionum	1.6
Sida sp.	1.6
Euphorbia drummondii	1.0
Neptunia dimorphantha	1.0
Sida goniocarpa	0.8
Indet. herb	0.8
Ptilotus exaltatus	0.6
Indet. herb	0.6
Aristida jerichoensis	0.4
Bassia lanicuspis	0.4
Rhynchosia minima	0.4
Sporobolus actinocladus	0.4
Phyllanthus maderaspatensis	0.4
Atriplex muelleri	0.2
Crotalaria dissitiflora	0.2
Malvastrum spicatum	0.2
Panicum whitei	0.2
Sporobolus australasicus	0.2
Polymeria marginata	0.2
Glycine falcata	0.2
Corchorus trilocularis	0.2
Indet. herb	0.2
Grass seedlings	0.6

No. of species recorded: 37

Basal Cover: 0.8%

Site No. 13.

Botanical Composition (%)

Thredkeldia proceriflora	46.4
Salsola kali	13.6
Bassia bicornis	10.0
Portulaca sp. aff. P. oleracea	6.2
Eragrostis setifolia	6.0
Portulaca filifolia	4.0
Astrebla lappacea	2.4
Sida sp.	2.4
Aristida latifolia	1.2
Astrebla elymoides	1.0
Iseilema membranaceum	0.8
Pterigeron adscendens	0.6
Solanum ellipticum	0.6
Goodenia sp.	0.4
Enneapogon polyphyllus	0.4
Tripogon loliiformis	0.4
Alternanthera nodiflora	0.4
Dactyloctenium radulans	0.2
Malvastrum spicatum	0.2
Bassia anisacanthoides	0.2
Rhynchosia minima	0.2
Atriplex muelleri	0.2
Chloris acicularis	0.2
Sporobolus actinocladus	0.2
Bassia lanicuspis	0.2
Hibiscus **trionum**	0.2
Kochia coronata	0.2
Rutidosis helichrysioides	0.2
Indet. herb	0.2
Minuria integerrima	0.2
Crotalaria dissitiflora	0.2
Grass seedlings	0.4

No. of species recorded:	31
Basal cover:	1.6%

Site No. 14.

Botanical composition (%)

Astrebla lappacea	39.2
Eragrostis setifolia	19.6
Astrebla elymoides	19.2
Hibiscus **trionum**	5.2
Sida sp.	4.0
Aristida sp.	2.6
Sporobolus actinocladus	1.8
Polymeria marginata	1.8
Iseilema membranaceum	1.4
Rhynchosia minima	0.8
Goodenia lunata	0.6
Dactyloctenium radulans	0.4
Enneapogon avenaceus	0.4
Evolvulus alsinoides	0.4
Portulaca filifolia	0.4
Astrebla squarrosa	0.4
Brachyachne convergens	0.2
Portulaca sp. aff. P. oleracea	0.2
Abutilon sp.	0.2
Herb seedlings	0.8
Grass seedlings	0.4

No. of species recorded: 19

Basal cover: 1.2%

Site No. 15.

Botanical Composition (%)

Evolvulus alsinoides	32.0
Aristida contorta	15.6
Abutilon sp.	9.6
Neurachne muelleri	7.8
Eragrostis eriopoda	6.4
Aristida jerichoensis	6.2
Enneapogon polyphyllus	4.0
Bassia birchii	3.4
Indigofera linifolia	2.6
Tripogon loliiformis	1.6
Tephrosia rosea var. augustifolia	1.2
Scaevola ovalifolia	1.2
Goodenia lunata	1.4
Triodia basedowii	1.4
Boerhavia diffusa	1.4
Portulaca sp. aff. P. oleracea	1.0
Kochia sp.	1.0
Euphorbia drummondii	0.6
Eriachne mucronata	0.6
Indigofera dominii	0.4
Neurachne mitchelliana	0.2
Polymeria marginata	0.2
Bassia sp.	0.2

No. of species recorded: 23

Basal cover: 1.2%

Site No. 16.

Botanical Composition (%)

Evolvulus alsinoides	26.6
Eragrostis eriopoda	13.6
Aristida contorta	10.4
Convolvulus sp.	10.4
Portulaca sp. aff. P. oleracea	8.2
Abutilon sp.	5.2
Bassia birchii	4.8
Neurachne muelleri	3.6
Indigofera linifolia	3.2
Tripogon loliiformis	2.6
Enneapogon polyphyllus	2.6
Goodenia ovalifolia	2.4
Goodenia lunata	1.6
Indet. herbs (2 spp.)	1.0
Aristida jerichoensis	0.8
Bassia sp.	0.8
Kochia sp.	0.6
Boerhavia diffusa	0.4
Indet. Cruciferae	0.4
Salsola kali	0.2
Sida sp.	0.2
Grass seedlings	0.2
Herb seedlings	0.2

No. of species recorded:	21
Basal cover:	3.2%

Site No. 17.

Botanical Composition (%)

Triodia basedowii	45.2
Evolvulus alsinoides	30.4
Aristida jerichoensis	4.4
Portulaca sp. aff. P. oleracea	3.8
Sida sp.	3.0
Aristida contorta	2.4
Abutilon sp.	3.8
Calandrinia balonensis	1.6
Crotalaria cunninghamii	1.2
Halganea cyanea	1.0
Swainsona microphylla ssp. tomentosa	0.6
Indet. herbs	0.6
Euphorbia eremophila	0.4
Enneapogon polyphyllus	0.4
Phyllanthus fuernrohrii	0.2
Eremophila bowmanii	0.2
Tephrosia rosea var. angustifolia	0.2
Ptilotus exaltatus	0.2
Ipomoea sp.	0.2
Herb seedlings	0.4

No. of seedlings recorded: 19

Basal cover: 7.2%*

* See footnote in site description.

Site No. 18.

Botanical Composition (%)

Triodia basedowii	68.6
Evolvulus alsinoides	9.2
Portulaca sp. aff. P. oleracea	6.0
Indet. herbs	4.0
Ipomoea muelleri	2.4
Abutilon sp.	2.4
Sida sp.	2.2
Enneapogon avenaceus	1.0
Bassia sp.	1.0
Eragrostis eriopoda	0.8
Portulaca filifolia	0.6
Hakea fraseri	0.6
Boerhavia diffusa	0.6
Eremophila sp.	0.6
Herb seedlings	0.6
Hibiscus sturtii	0.4
Calandrinia balonensis	0.2
Aristida jerichoensis	0.2
Acacia seedlings	0.2
Grass seedlings	0.2

No. of species recorded:	18
Basal cover:	11.2%*

* See footnote in site description of Site 17.

Site No. 19.

Botanical Composition (%)

Indet. spineless Chenopodaceae	42.6
Bassia divaricata	25.6
Bassia convexula	7.6
Bassia brachyptera	7.2
Kochia triptera	2.6
Sida fibulifera	2.6
Bassia patenticuspis	2.6
Tragus australianus	1.8
Atriplex stipitata	1.2
Solanum ellipticum	0.8
Atriplex semibaccata	0.6
Dactyloctenium radulans	0.4
Portulaca filifolia	0.4
Bassia paradoxa	0.4
Boerhavia diffusa	0.8
Malvastrum spicatum	0.6
Enneapogon polyphyllus	0.2
Atriplex sp.	0.2
Sida sp.	0.2
Salsola kali	0.2
Indet. herb	0.2
Herb seedlings	1.8

No. of species recorded:	21
Basal cover:	0.2%

Site No. 20.

Botanical Composition (%)

Eriachne mucronata	35.2
Aristida contorta	26.6
Amphipogon caricinus	10.8
Sida sp.	6.0
Neurachne mitchelliana	5.2
Goodenia sp.	4.4
Eragrostis eriopoda	3.6
Solanum ellipticum	1.2
Kochia tomentosa	1.0
Eremophila latrobei	1.0
Kochia sp.	0.6
Indet. herb	0.6
Digitaria brownei	0.2
Eremophila bowmanii	0.2
Bassia calcarata	0.2
Acacia aneura	0.2
Grass seedlings	1.8
Herb seedlings	0.8

No. of species recorded: 16

Basal cover: 0.8%

Site No. 21.

Botanical Composition (%)

Indet. spineless Chenopodaceae	30.0
Kochia triptera	9.8
Sida sp.	8.4
Bassia divaricata	6.0
Salsola kali	5.2
Acacia aneura	3.8
Aristida jerichoensis	3.8
Danthonia bipartita	3.4
Phyllanthus fuernrohrii	3.2
Neurachne mitchelliana	3.0
Fimbristylis dichotoma	2.2
Kochia tomentosa	2.2
Bassia sp.	1.8
Tripogon loliiformis	3.6
Eragrostis eriopoda	1.4
Eriachne mucronata	1.4
Digitaria brownei	1.4
Indet. herbs	1.8
Enneapogon polyphyllus	0.6
Eremophila longifolia	0.6
Aristida ingrata	0.6
Eremophila latrobei	0.4
Helipterum floribundum	0.4
Dactyloctenium radulans	0.2
Solanum ellipticum	0.2
Grass seedlings	0.8
Herb seedlings	0.4

No. of species recorded: 25

Basal cover: 0.6%

Site No. 22.

Botanical Composition (%)

Dichanthium sericeum	39.6
Eragrostis setifolia	11.4
Iseilema membranaceum	8.2
Bassia quinquecuspis	6.4
Dactyloctenium radulans	5.4
Cyperus bifax	3.8
Astrebla lappacea	3.4
Hibiscus trionum	3.4
Marsilea hirsuta	2.8
Eriochloa pseudoacrotricha	2.2
Minuria integerrima (?)	2.2
Digitaria ammophila	1.8
Eragrostis tenellula	1.6
Eleocharis pallens	1.4
Ixiolaena brevicompta	0.8
Portulaca sp. aff. P. oleracea	0.8
Panicum decompositum	0.6
Phyllanthus maderaspatensis (?)	0.6
Eragrostis lacunaria	0.4
Solanum sp.	0.4
Polymeria marginata	0.4
Sida sp.	0.4
Bassia brachyptera	0.4
Boerhavia diffusa	0.2
Alternanthera nodiflora	0.2
Herb seedlings	1.2

No. of species recorded: 25

Basal cover: 3.0%

Site No. 23.

Botanical Composition (%)

Sida sp. (S. trichopoda form)	15.0
Desmodium campylocaulon	10.2
Sida filiformis	9.4
Salsola kali	7.4
Dichanthium sericeum	7.4
Minuria sp.	6.6
Astrebla lappacea	6.4
Digitaria ammophila	5.0
Indet. herbs (5 spp.)	5.0
Malvastrum spicatum	4.8
Ptilotus exaltatus	4.0
Iseilema membranaceum	3.8
Plantago pritzelii	3.4
Panicum decompositum	2.6
Goodenia sp.	1.4
Bassia calcarata	1.2
Brachyachne convergens	0.8
Craspedia chrysantha	0.8
Bassia sp.	0.6
Enneapogon polyphyllus	0.4
Solanum ellipticum	0.4
Eragrostis eriopoda	0.4
Neptunia gracilis	0.2
Rhynchosia minima	0.2
Aristida latifolia	0.2
Indet. legume	0.2
Kochia sp.	0.2
Polymeria marginata	0.2
Dactyloctenium radulans	0.2
Grass seedlings	1.6

No. of species recorded: 29

Basal Cover: 1.8%

Site No. 24.

Botanical Composition (%)

Sida sp.	40.8
Astrebla lappacea	15.0
Kochia sp.	10.6
Iseilema membranaceum	7.2
Solanum ellipticum	5.4
Eragrostis sp.	2.8
Goodenia sp.	2.6
Aristida sp.	2.4
Minuria sp.	1.6
Enneapogon polyphyllus	1.6
Malvastrum spicatum	1.4
Salsola kali	1.2
Plantago pritzelii	1.0
Portulaca sp. aff. P. oleracea	1.0
Digitaria ammophila	0.6
Bassia sp.	0.6
Rhynchosia minima	0.4
Sporobolus caroli	0.4
Atriplex sp.	0.4
Desmodium campylocaulon	0.4
Atriplex muelleri	0.2
Trianthema triquetra	0.2
Indet. herb	0.2
Panicum whitei	0.2
Dichanthium sericeum	0.2
Glycine falcata ?	0.2
Herb seedlings	0.8
Grass seedlings	0.6

No. of species recorded:	26
Basal cover:	2.4%

Site No. 25.

Botanical Composition (%)

Amphipogon caricinus	47.8
Neurachne mitchelliana	19.8
Danthonia bipartita	8.6
Aristida sp.	7.2
Sida sp.	3.4
Digitaria brownei	2.8
Eriachne helmsii	2.8
Acacia aneura	1.6
Eragrostis eriopoda	1.2
Cheilanthes sieberi	1.0
Digitaria ammophila	1.0
Evolvulus alsinoides	0.6
Eragrostis setifolia	0.4
Bassia sp.	0.4
Kochia sp.	0.2
Boerhavia diffusa	0.2
Sida sp. (S. platycalyx ?)	0.2
Enneapogon polyphyllus	0.2
Grass seedlings	0.6

No. of species recorded:	18
Basal cover:	3.8%

Site No. 26.

Botanical Composition (%)

Amphipogon caricinus	94.6
Eragrostis eriopoda	1.4
Neurachne mitchelliana	0.8
Aristida jerichoensis	0.2
Atriplex sp.	0.2
Eremophila gilesii	0.2
Euphorbia drummondii	0.2
Grass seedlings	2.4

No. of species recorded:	7
Basal cover:	1.8%

Site No. 27.

Botanical Composition (%)

Aristida jerichoensis	72.2
Digitaria ammophila	11.2
Danthonia bipartita	4.2
Cheilanthes sieberi	3.0
Eragrostis setifolia	2.8
Neurachne mitchelliana	2.2
Neurachne sp. (N. mitchelliana ?)	1.0
Digitaria brownei	0.6
Enneapogon polyphyllus	0.6
Themeda australis	0.4
Eragrostis parviflora	0.4
Amphipogon caricinus	0.4
Bulbostylis barbata	0.2
Ptilotus macrocephalus	0.2
Tripogon loliiformis	0.2
Tragus australianus	0.2
Brachiaria piligera	0.2

No. of species recorded: 17

Basal cover: 5.4%

Site No. 28.

Botanical Composition (%)

Digitaria ammophila	23.0
Aristida jerichoensis	21.6
Tripogon loliiformis	19.4
Cheilanthes sieberi	12.6
Danthonia bipartita	3.4
Enneapogon polyphyllus	2.4
Digitaria brownei	2.2
Eragrostis sp.	2.0
Neurachne sp. (N. mitchelliana ?)	1.4
Brachiaria piligera	1.4
Fimbristylis dichotoma	1.2
Neurachne mitchelliana	1.0
Tragus australianus	0.6
Evolvulus alsinoides	0.4
Acacia aneura	0.4
Ptilotus macrocephalus	0.2
Eragrostis eriopoda	0.2
Aristida contorta	0.2
Grass seedlings	3.4
Herb seedlings	3.0

No. of species recorded: 18

Basal cover: 1.4%

Site No. 29.

Botanical Composition (%)

Danthonia bipartita	30.2
Aristida jerichoensis	17.6
Themeda australis	14.4
Digitaria brownei	11.2
Aristida contorta	9.6
Digitaria hubbardiana	5.0
Kochia sp.	3.0
Eragrostis sp.	2.6
Eriachne helmsii	1.0
Bassia birchii	0.6
Evolvulus alsinoides	0.6
Portulaca filifolia	0.6
Eragrostis eriopoda	0.6
Digitaria ammophila	0.4
Sida sp.	0.4
Abutilon sp.	0.4
Indet. herb	0.2
Bassia brachyptera	0.2
Ptilotus exaltatus	0.2
Perotis rara	0.2
Neurachne mitchelliana	0.2
Eragrostis microcarpa	0.2
Grass seedlings	0.6

No. of species recorded: 22

Basal cover: 3.4%

Site No. 30.

Botanical Composition (%)

Astrebla lappacea	59.6
Sida sp.	20.8
Sporobolus actinocladus	5.4
Malvastrum spicatum	4.6
Solanum esuriale	3.2
Dichanthium sericeum	2.6
Panicum whitei	0.6
Astrebla elymoides	0.6
Brachyachne convergens	0.6
Aristida sp.	0.2
Aristida latifolia	0.2
Eragrostis setifolia	0.2
Grass seedlings	0.8
Herb seedlings	0.6

No. of species recorded: 12

Basal cover: 7.6%

Site No. 31.

Botanical Composition (%)

Astrebla lappacea	39.4
Iseilema spp.	22.2
Dactyloctenium radulans	17.6
Portulaca sp. aff. P. oleracea	5.4
Brachyachne convergens	4.4
Malvastrum spicatum	2.4
Bassia anisacanthoides	2.0
Cyperus bifax	1.4
Desmodium sp.	1.0
Bassia calcarata	0.6
Phyllanthus maderaspatensis	0.6
Eragrostis sp.	0.4
Sida sp.	0.4
Acacia cambagei seedling	0.2
Astrebla elymoides	0.2
Eriachne aristideae	0.2
Euphorbia sp.	0.2
Trianthema triquetra	0.2
Grass seedlings	1.2

No. of species recorded:	18
Basal cover:	3.8%

Site No. 32

Botanical Composition:

Astrebla lappacea	39.8
Astrebla elymoides	30.2
Bassia bicornis var. horrida	14.4
Bassia anisacanthoides	4.2
Portulaca sp. aff. P. oleracea	3.6
Abutilon malvifolium	0.6
Cyperus bifax	0.6
Desmodium sp.	0.6
Iseilema spp.	0.4
Enneapogon polyphyllus	0.4
Indet. herb	0.4
Sporobolus caroli	0.4
Boerhavia diffusa	0.2
Eriachne aristideae	0.2
Malvastrum spicatum	0.2
Salsola kali	0.2
Sporobolus actinocladus	0.2
Grass seedlings	3.4

No. of species recorded: 18

Basal cover: 5.4%

Site No. 33.

Botanical Composition: (%)

Astrebla lappacea	32.0
Aristida latifolia	13.6
Eriachne aristideae	11.2
Goodenia subintegra	5.2
Bassia aniscanthoides	4.6
Malvastrum spicatum	4.0
Cyperus bifax	3.6
Astrebla elymoides	3.0
Sida sp.	2.8
Rhynchosia minima	2.4
Panicum queenslandicum	2.2
Atriplex muelleri	1.8
Desmodium sp.	1.8
Dichanthium sericeum	1.6
Sporobolus actinocladus	1.6
Indet. herbs (2 spp.)	1.6
Portulaca filifolia	0.8
Abutilon malvifolium	0.6
Bassia bicornis	0.6
Eriochloa pseudoacrotricha	0.6
Kochia sp.	0.6
Tripogon loliiformis	0.6
Eulalia fulva	0.4
Iseilema membranaceum	0.4
Abutilon sp.	0.2
Indet. herb	0.2
Dactyloctenium radulans	0.2
Eragrostis setifolia	0.2
Glycine sp.	0.2
Phyllanthus maderaspatensis	0.2
Portulaca sp. aff. P. oleracea	0.2
Grass seedlings	1.0

No. of species recorded: 32

Basal cover: 3.4%

Site No. 34.

Botanical Composition (%)

Astrebla lappacea	68.2
Astrebla elymoides	9.2
Salsola kali	7.2
Iseilema spp.	4.2
Boerhavia diffusa	1.6
Eriachne aristideae	1.4
Sida sp.	1.4
Atriplex muelleri	1.2
Bassia anisacanthoides	1.2
Aristida latifolia	1.0
Cyperus retzii	0.8
Threlkeldia proceriflora	0.6
Ptilotus sp.	0.4
Bassia quinquecuspis	0.2
Neptunia sp.	0.2
Panicum queenslandicum	0.2
Rhynchosia minima	0.2
Sporobolus actinocladus	0.2
Sporobolus caroli	0.2
Trianthema triquetra	0.2
Grass seedlings	0.2

No. of species recorded:	21
Basal cover:	3.2%

Site No. 35.

Botanical Composition: (%)

Astrebla lappacea	25.0
Astrebla spp.	14.0
Malvastrum spicatum	8.6
Aristida latifolia	8.2
Dactyloctenium radulans	7.0
Astrebla elymoides	6.8
Cyperus bifax	4.4
Eragrostis setifolia	3.6
Sporobolus actinocladus	4.8
Bassia quinquecuspis	2.8
Polymeria marginata	2.6
Bassia birchii	2.4
Iseilema spp.	2.0
Boerhavia diffusa	1.2
Brachyachne convergens	1.2
Glycine falcata	1.2
Sporobolus caroli	0.6
Atriplex sp.	0.6
Sida sp.	0.6
Tragus australianus	0.6
Chrysopogon fallax	0.4
Sida fibulifera	0.4
Acacia cambagei	0.2
Bassia aniscanthoides	0.2
Eriachne aristideae	0.2
Panicum whitei	0.2
Rhynchosia minima	0.2

No. of species recorded:	27
Basal cover:	5.2%

Site No. 36.

Botanical Composition (%)

Astrebla lappacea	34.4
Salsola kali	12.2
Astrebla elymoides	9.8
Polymeria marginata	6.4
Astrebla spp.	4.4
Brachyachne convergens	3.0
Astrebla pectinata	2.2
Aristida latifolia	2.0
Malvastrum spicatum	2.0
Sida fibulifera	1.4
Panicum decompositum	1.4
Indet. herb	1.0
Astrebla squarrosa	0.8
Digitaria sp.	0.8
Indet. herb	0.6
Boerhavia diffusa	0.6
Enneapogon polyphyllus	0.4
Acacia farnesiana	0.2
Bassia quinquecuspis	0.2
Dichanthium sericium	0.2
Eragrostis setifolia	0.2
Teucrium integrifolium	0.2
Tragus australianus	0.2
Grass seedlings	15.4

No. of species recorded: 22

Basal cover: 3.4%

Site No. 1.

Location: In Railway Reserve near Bierbank Siding on Beechal Creek.

Position of Survey Site: Five yards inside northern fence, from 200 yards west of 571½ milepost to 200 yards west of 571 milepost.

Notes: Hard red soil, virtually level, no water ponding effect of railway line. Outside the Reserve is open Box country from which Mulga has been removed, with a ground cover of Aristida contorta, Eragrostis eriopoda and Neurachne helmsii. Much Eremophila gilesii and bare soil outside Reserve.

History: Fenced early 1900's. Not grazed by domestic stock, grazed by wild animals, burnt at regular intervals.

Site No. 2.

Location: In Railway Reserve immediately west of Cooladdi Siding.

Position of Survey Site: Six yards inside northern fence from 546½ milepost to 50 yards east of 547 milepost.

Notes: Level Box country in which Mulga has been partially removed. Mulga seedlings present in considerable numbers in Reserve. No noticeable ponding effect of railway line.

History: As for Site 1.

Site No. 3.

Location: In Railway Reserve immediately west of Yallamurra Siding.

Position of Survey Site: Five yards inside northern fence, from 200 yards east of 556½ milepost to 556 milepost. Not surveyed between the two creek fences running at right angles to the outside Reserve fences.

Notes: This sample covers three communities namely, sparse "ridge mulga" on hard red soil, a run on area on level ground west of the creek and a "clay pan" type community at the eastern end of the survey.

History: As Site No. 1.

Site No. 4.

Location: Approximately two miles west of Winbin Siding, in Railway Reserve.

Position of Survey Site: Three yards south of northern Reserve fence, from 596½ milepost to 200 yards west of 596 milepost, taking 120 points on second run over same sample line.

Notes: The western end of this sample is bare hard gravelly mulga soil, the remainder being typical hard mulga country in this area. Slight slope, no ponding effect of railway line on survey site.

History: As for Site 1.

Site No. 5.

Location: In Railway Reserve, approximately eight miles west of Cheepie Siding.

Position of Survey Site: Four yards south of northern fence, from culvert at 200 yards west of 581½ milepost to 20 yards east of trolley lines, where second run on same line was taken.

Notes: Run on area, with two bare areas within sample. Occasional *Astrebla lappacea* plants present in *Themeda* community. Red loam soil.

History: As for Site 1.

Site No. 6.

Location: Main road reserve, adjacent to Railway Reserve, six miles east of Winbin Siding.

Position of Survey Site: Starting at crest of rocky plateau 200 yards south of 587 railway milepost and taking 276 points in a south western direction before turning 50 yards north and proceeding north east with a parallel run to the previous one.

Notes: Very rocky, almost soilless plateau dominated by *Eriachne mucronata* and *Amphipogon caricinus*. Almost treeless except for occasional Bloodwood and Mulga trees. Almost level terrain.

History: Survey area falls between the main road and the railway line. Grazing history not certain.

Site No. 7.

Location: In Railway Reserve, approximately 2 miles west of Coolbinga Siding.

Position of Survey Site: Three yards south of northern fence, proceeding west at first telephone pole west of 601 milepost and reversing direction at waterway after 260 points.

Notes: Hard red mulga soil with several depressions. Sloping terrain in open mulga country.

History: As for Site No. 1.

Site No. 8.

Location: In Railway Reserve, approximately 6 miles west of Coolbinga Siding.

Position of Survey Site: Three yards north of southern fence, proceeding east from white post at ¼ mile east of 605 milepost, reversing direction after 280 points and proceeding on line of first run.

Notes: Level terrain of Gidyea alluvium near creek. Potentially Astrebla, presently chenopods.

History: As for Site No. 1.

Site No. 9.

Location: In Railway Reserve approximately 12 miles east of Quilpie.

Position of Survey Site: Five yards north of southern fence, proceeding east from 612½ milepost for 240 points and returning west on same line to west of 612½ milepost.

Notes: Level sand loam in open mulga country, displaying a striking fence-line contrast.

History: As for Site No. 1.

Site No. 10.

Location: In Railway Reserve approximately 6 miles east of Bierbank Siding.

Position of Survey Site: One yard north of southern fence, starting at 567½ milepost and proceeding westwards for 340 points before reversing direction along the same line.

6

Site No. 10 cont.

Notes: Sloping terrain, hard red stony mulga soil, no ponding effect of railway line.

History: As for Site 1.

Site No. 11.

Location: Charleville airfield.

Position of Survey Site: Immediately south of the east-west runway, 500 yards from the Boatman road, starting from access road and running $\frac{1}{4}$ mile east and returning $\frac{1}{4}$ mile 40 yards south of first line.

Notes: Red loam soil of "soft mulga" country. Level ground, survey site not affected by runoff from runway.

History: Trees removed during early 1940's. Protected from grazing since 1946. Occasionally burnt.

Site No. 12.

Location: Yaraka airfield.

Position of Survey Site: Fifty yards south of east-west runway starting at small group of trees near middle of the airfield and proceeding east for $\frac{1}{4}$ mile and returning parallel to first run but 30 yards south of it.

Notes: Open Boree-Gidyea woodland country. Grey-brown cracking clay on level terrain near creek.

History: Cleared before 1960, seldom ever grazed by domestic stock. Particulars concerning fencing require verification.

Site No. 13.

Location: Stonehenge airstrip.

Position of Survey Site: Starting 7 yards east of north-south fence (at eastern end of runway) and proceeding from 20 yards south of strip for 300 points before reversing direction and taking remainder of points.

Notes: Open Gidyea country. Grey-brown cracking clay carrying a sparse cover of chenopods. Apparently poor reaction to protection. Perennial grasses virtually limited to depressions where Bothriochloa,

Site No. 13 cont.

Eragrostis, Astrebla and Sporobolus form gilgai communities.

History: Fenced in early 1960's, seldom grazed since then, except occasionally by goats. Apparently heavily grazed in earlier years.

Site No. 14.

Location: Jundah Town Common reserve paddock, approximately 2 miles north east of Jundah.

Position of Survey Site: Starting 300 yards north of common fence gridgate and 100 yards north west of the main road, proceeding in the direction of the gridgate for ¼ mile and reversing direction for ¼ mile 40 yards west of first run.

Notes: Very good stand of Mitchell grass is present, on open Gidyea plain. Astrebla lappacea and A. elymoides not distinguishable on micro-habitat specificity. Grey-brown cracking clay.

History: Fenced since 1940's, used only occasionally for grazing town stock during serious drought.

Site No. 15.

Location: Jundah town race course enclosure.

Position of Survey Site: Two parallel runs 40 yards apart down the centre of the long axis of the oval within the race course.

Notes: Red sandy loam in cleared open Mulga - Bloodwood country. Level terrain.

History: Cleared and fenced during the early 1940's, grazed very lightly by a few horses.

Site No. 16.

Location: Jundah golf course, portion of town common.

Position of Survey Site: Starting 30 yards south of club house, proceeding 200 yards south then in a straight line, 40 yards east of first run, going north for approximately ½ mile between fairways.

Notes: Open sandy Bloodwood-Mulga country. Virtually level terrain adjoining hospital grounds.

History: Lightly grazed by cattle since early 1940's.

Site No. 17.*

Location: Windorah town cemetery on western extremity of town.

Position of Survey Site: Starting near south east corner, proceeding north west in four parallel diagonal runs across fenced area.

Notes: Loose red sand between two sand dunes. Large spinifex tufts in Grevillea-Bloodwood open plains.

History: Fenced early 1900's, not grazed or burnt.

* Due to excessive deposition of windblown sand under spinifex tufts, definition of a "strike" by the wheel-point apparatus had to be re-defined for sites 17 and 18. A strike in these cases was recorded whenever the point was judged to be within the "rooted basal area" of the tuft. This definition is responsible for the relatively high basal cover recordings in spinifex communities.

Site No. 18.*

Location: Windorah airfield, approximately one mile east of Windorah town.

Position of Survey Site: Starting on eastern boundary fence of airfield approximately $\frac{3}{4}$ mile from the main (sealed) road, proceeding westward toward airfield buildings.

Notes: Similar community to Site 17 but soil somewhat firmer sand and anthills more prominent.

History: Fenced 1963, not grazed by domestic stock since.

* See footnote for Site No. 17.

Site No. 19.

Location: Western "hill paddock", "Wittenburra", approximately 30 miles south west of Eulo.

Position of Survey Site: West of Walls of China hills, $8\frac{1}{2}$ miles west of homestead, commencing from open area between trees shown in Plate 19 in a north eastern direction for 150 yards then proceeding south for approximately $\frac{1}{2}$ mile to near watercourse.

Notes: Sloping terrain in open Gidyea country at the foot of rocky hills. Brown stoney cracking clay carrying very little grass. Regarded as very good sheep carrying country.

Site No. 19 cont.

History: Not grazed by domestic stock since 1952, except for one occasion of a few months when mulga was pushed in drought. Kangaroos apparently abundant judging by cropped grass.

Site No. 20.

Location: Summit plateau of "hill paddock" in the Walls of China hills on "Wittenburra", approximately 30 miles south west of Eulo.

Position of Survey Site: Starting at southern edge of plateau at site shown in Plate 20 and proceeding north for ¼ mile and then south west for ¼ mile.

Notes: Very rocky plateau, almost soilless, very similar to Site No. 6 physiographically and botanically. Slight slope on portion of the survey area. Several slight depressions. Occasional stunted mulgas. All grasses except Eriachne mucronata grazed short by wildlife.

History: Not grazed by domestic stock since 1952 but apparently grazed by kangaroos and goats, judging by cropped grass.

Site No. 21.

Location: North eastern portion of "hill paddock", "Wittenburra", approximately 30 miles south west of Eulo.

Position of Survey Site: Against eastern fence in triangle of three runs of ⅓ mile each, proceeding from big Box tree on car track to eastern fence as base of triangle.

Notes: Stony mulga country, heavy red soils with mixed Dogwood, Supplejack, Whitewood, Box, Leopardwood and Dead Finish bush. Soil softer in patches. Apparently grazed by wild life.

History: Not grazed by sheep since 1952, except for one occasion on which sheep were fed pushed mulga for a few months during drought. Grass cropped short by wildlife in all but sites protected by fallen trees.

Site No. 22.*

Location: Back Paddock, "Bluegrass", approximately sixty miles south of Cunnamulla.

Position of Survey Site: Starting at position near Coolibah trees shown in Plate 22, proceeding north west for $\frac{1}{4}$ mile then reversing direction back to starting point.

Notes: Heavy black soil, ponded situation behind artificial flood bank. Dogwood and Lignum also present.

History: Flooded twice since early 1960's. Grazed by sheep in normal management programme.

* This is not a protected site comparable to the other sites in this study but is representative of the best development of Dichanthium grassland in southern Queensland and as such may be regarded as a standard for this type of situation until more quantitative data is available.

Site No. 23.

Location: "South oestrus" paddock reserve, "Gilruth Plains", approximately 20 miles east of Cunnamulla.

Position of Survey Site: Starting at the small dam on the northern fence, proceeding diagonally to the south-west corner, then east to the drain, then diagonally to the north-west corner, then east to the starting point.

Notes: Heavy grey brown clay, very severely cracked. Open plain of Mitchell grass adjoining Gidyea at foot of sandhill. No survey carried out in Gidyea or Pine communities.

History: Reserve was dog netted in early 1940's and has been completely protected from all animals and fire since fencing. This is probably the only fully protected vegetation in south west Queensland and includes Mitchell flats, Gidyea and Spinifex in Pine tree sand hills.

Site No. 24.*

Location: Paddocks adjoining "South Oestrus" paddock reserve, "Gilruth Plains", approximately 20 miles east of Cunnamulla.

Position of Survey Site: Starting 20 yards outside the southern fence of the reserve (Site No. 23) at the drain and proceeding west to the south western corner of the reserve. Continuing north 20 yards outside western fence of the reserve, then eastwards 10 yards north of the northern reserve fence.

Notes: Soil and situation the same as for Site 23, but grazed by sheep under normal management, having never been preserved in any way.

History: Normal grazing treatment under sheep.

* This site is not a preserved area but is included for comparison with Site 23 adjoining it.

Approximate comparisons of selected species:

	Reserved for 30 years		Not reserved
Sida spp.	24%	of botanical composition	40%
Malvastrum	5%		1%
Dichanthium	7%		1%
Salsola kali	7%		1%
Astrebla lappacea	4%		15%
Legumes	12%		1%

Site No. 25.

Location: Front paddock (adjoining main road) "Dingwall", Nebine, approximately 80 miles south south-east of Charleville.

Position of Survey Site: Starting from Box tree in Plate 25 and proceeding west for $\frac{1}{3}$ mile, then south-east for $\frac{1}{3}$ mile then north east to starting point.

Notes: Well managed open Mulga-Box country. Soft red earth, no stones.

History: Used for winter grazing only for many years (1922-1949) but lately used continuously but lightly for cattle.

Site No. 26.

Location: Horse paddock (immediately south of outstation buildings), "Woodvale", Nebine, approximately 110 miles south south-east of Charleville.

Position of Survey Site: Starting in south-eastern corner against the boundary fence, proceeding north for 120 points, then south-west for 140 points, then east for 100 points, then north 100 points.

Notes: Shallow stony hard red earth on the top of a ridge, some ironstone exposed on the surface. Sparse mulga, ground cover completely dominated by Amphipogon which is apparently grazed by wild life. A very poor cover in response to the spelling this paddock has allegedly had.

History: Originally portion of sheep paddock. One night horse since late 1940's to late 1950's then not grazed at all from late 1950's to 1971, except for the occasional stray sheep. No rabbits since 1940.

Site No. 27.

Location: Mulga Density Trial, "Boatman" Station, Nebine, approximately 75 miles south south-east of Charleville.

Position of Survey Site: Plot A1 (NW corner of trial) starting at gate in north western corner and proceeding in parallel runs, 5 yards apart, over the entire plot.

Notes: Mulga thinned to 40 trees/ha in 1963 which has led to a dense cover of tall Aristida. Level terrain, red loam soil.

History: Partially cleared and net fenced in 1963. Completely protected from grazing and fire since then. Felled timber not removed and still not decayed. Despite netting, there are occasional signs that kangaroos have entered the trial area.

Site No. 28.

Location: Mulga Density Trial, "Boatman" Station, Nebine, approximately 75 miles south south-east of Charleville.

Site No. 28 cont.

Position of Survey Site: Plot B3 (adjoining A1) starting in north west corner of plot and proceeding in parallel runs 5 yards apart over entire plot.

Notes: Mulga standing 640 trees/ha, completely overshadowing all ground cover to the extent that virtually all grasses recorded in the survey are weak spindly seedlings and not well established tufts as in the sunny border strip in Plate 28. It is suggested that the obvious association between Digitaria ammophila seedlings and fallen timber may be primarily a mechanical effect of rolling wind-blown inflorescences being retained by the obstructions of fallen branches. This association has been observed at several sites and may thus not be a direct fertility or moisture causal relationship.

History: As for Site 27.

Site No. 29.

Location: Wyandra town airfield, approximately ½ mile south-east of Wyandra.

Position of Survey Site: Starting at the eastern end of the runway, 40 yards south of the fence along the Wyandra-Boatman road and proceeding for ¼ mile west then reversing direction for a return run of ¼ mile 10 yards north of the first run.

Notes: Soft red loam in cleared Mulga-Box country similar to Site No. 11. Signs of previous local disturbance in the survey area, giving a patchy distribution of Bassia. Level terrain.

History: Fenced in early 1960's when airfield was moved to this new site. Not grazed by domestic stock since fencing.

Site No. 30.

Location: North western Reserve Paddock, "Warrego Park", approximately four miles west of Wyandra.

Position of Survey: Starting 20 yards north-west of bore drain and proceeding for ¼ mile towards double-stemmed Gidyea tree shown in Plate 30, then reversing direction for ¼ mile 20 yards south of first run back to the starting point.

Site No. 30 cont.

Notes: Good example of southern Mitchell grass plains in very good order. Heavy grey clay, level terrain of Warrego flats, interspersed with clumps of Gidyea.

History: Very lightly grazed with sheep from approximately 1930 to 1956. Since 1956, spelled for seeding after virtually every good rain.

Site No. 31.

Location: In railway reserve at Glen Stuart Siding.

Position of Survey Site: Midway between line and fence on north side of line adjacent to the siding sign, to within 5 yards of loading ramp then 20 yards north then follow fence west.

Notes: Mitchell grass downs with open boree woodland and patchy gidyea. Soil is typical grey brown cracking clay, not receiving run-off water.

History: Fenced 1913, grazed by wild animals but not livestock, burnt at regular intervals.

Site No. 32.

Location: In railway reserve immediately east of road-crossing, east of Malverton Siding.

Position of Survey: Two yards inside fence on south side starting at third telegraph post and going east.

Notes: Mitchell grass downs. Soil is grey-brown cracking clay.

History: Fenced 1913, grazed by wild animals but not domestic livestock, burnt at regular intevals.

Site No. 33.

Location: In railway reserve along Yaraka road east of turnoff to Isisford road.

Position of Survey Site: Midway between fence and line starting at 99½ milepost going east on south side of the line.

Site No. 33 cont.

Notes: Mitchell grass downs with scattered boree and gidyea. Soil is grey-brown cracking clay.

History: Fenced 1913, grazed by wild animals but not domestic livestock, burnt at regular intervals.

Site No. 34.

Location: In railway reserve at Benlidi Siding.

Position of Survey Site: Midway between line and fence on south side going east starting 5 yards east of road into siding.

Notes: Mixed gidyea/boree/downs on cracking clay.

History: Fenced 1913, grazed by wild animals but not domestic livestock, burnt at regular intervals.

Site No. 35.

Location: "Koondoo" 75 miles south of Blackall on Blackall-Adavale Road.

Position of Survey Site: Half a mile south of turnoff to homestead where a water drain has been laid under the road. The drain is marked by two posts, one on either side of the road.

Notes: Mitchell grass downs country with scattered timber - mainly gidyea. This is not a protected site but is regarded as the "best" Mitchell grass country on "Koondoo".

History: This property has been in the family since before 1950. The owner-manager has never stocked at a stocking rate in excess of 1 sheep/3 acres.

Site No. 36.

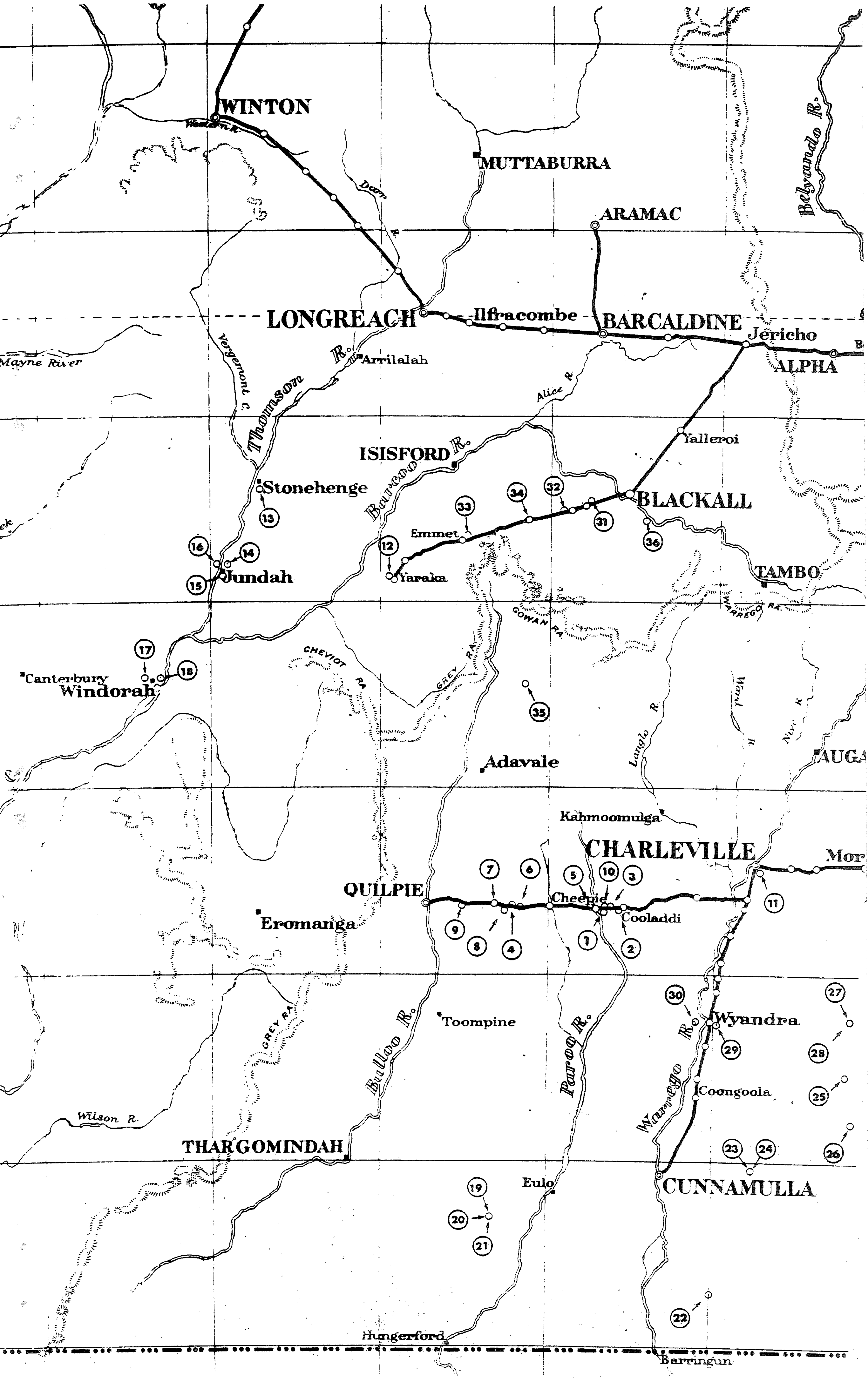
Location: "Duneira" 10 miles south of Blackall running along the Barcoo River.

Position of Survey Site: Starting from the south western corner post the survey ran north from the fourth, sixteenth and twenty-third posts on the southern fence and south from the eighth and twentieth posts on the northern fence. At each post the survey started ten paces in from the post.

Site No. 36 cont.

Notes: This exclosure has been grazed in the past and at present has a high protective fence on three sides only. Evidence of recent grazing was apparent.

History: This exclosure of 6 acres was erected in 1936 with an adjacent grazed area also of 6 acres. A bore drain put through the grazed area later allowed stock access to the exclosed area which was subsequently fenced off with a normal fence.



WINTON
Western R.
MUTTABURRA
Darr R.
ARAMAC
Belyando R.
LONGREACH
Ilfracombe
BARCALDINE
Jericho
ALPHA
Mayne River
Vergemont C.
Thomson R.
Arrilalah
Alice R.
Yalleroi
ISISFORD
Barcoo R.
Stonehenge
BLACKALL
Emmet
Yaraka
Jundah
TAMBO
WARREGO RA.
GOWAN RA.
CHEVIOT RA.
GREY RA.
Canterbury
Windorah
Ward R.
Nive R.
Langlo R.
Adavale
AUGA
Kahmoomulga
CHARLEVILLE
Mor
QUILPIE
Cheepie
Cooladdi
Eromanga
Wyandra
Toompine
Bulloo R.
Paroo R.
Warrego R.
Coongoola
GREY RA.
Wilson R.
THARGOMINDAH
CUNNAMULLA
Eulo
Hungerford
Barringun