TO

THE AUSTRALIAN WOOL CORPORATION

GRAZING LAND RODUCTIVITY AND STABILITY

Project number K/2/900 (B)

(Previously part of K/2/900 (originally W.R.T.F. Project 6) - Pasture Improvement and Forage Cropping)

Compiled by I.F. Beale
Charleville Pastoral Laboratory
Queensland Department of Primary Industries
P.O. Box 282
Charleville, Qd. 4470

Queensland Department of Primary Industries

Brisbane

March 1986

ABSTRACT

When this project began there was little detailed knowledge of the soil-water-plant-animal complex and their interactions in western Queensland. In the course of this project, the state of knowledge of this complex has been expanded greatly. It has increased our knowledge of the productive value of useful woody species (particularly mulga) and made us aware of the problem of increasing populations of woody species and of their potential destructive effect on animal production. The project has contributed a large number of associated publications on the management of woody plant communities in south west Queensland. This material has also been extended to graziers and land administration personnel concerned with the area.

Management of these areas needs to consider:-

* Population monitoring has confirmed the problem of expansion of woody species, particularly weed species such as sandalwood, turpentine, green and grey turkeybush, and hopbush.

* Forage yields decrease with increasing woody plant densities, while the amount of forage available from edible woody species (particularly mulga) increases. Pasture plant densities (i.e. ground cover) also decrease with higher densities of woody species.

* Woody species germination and survival are favoured by cool season rain.

* Thinning of mulga scrubs can lead to large increases in woody weed populations.

* Seed production from mulga is adequate for continual recruitment. Survival of regrowth is dependent on season and animal management.

* Woody plants make more efficient use of the small supply of available nutrients (particularly phosphorus) in mulga soil and become dominant over grasses with time.

* Protection from grazing for 20 years has not caused major improvement in botanical composition of pastures in degraded areas, while woody plants have benefited.

* Protection of mitchell grass (*Astrebla* spp.) pastures from grazing has caused degeneration of the mitchell grass and has had no effect on associated problem *Aristida* species.

* Control of woody weed species can be achieved by commonly available chemicals, but these are only economical in special circumstances at present costs and returns. Other control measures (e.g. fire) need to be investigated.

* Water use by vegetation was lowest on sites totally cleared of mulga. Soil moisture levels were at or below wilting point within 70 days after total recharge.

* Surface runoff was greater in hard mulga and residual land zones than in soft mulga. Ground cover reduces runoff, and a cover of at least 2% basal area is considered essential to reduce soil and nutrient loss.

* Mulga soil has a concentration of nutrients in the upper 5cm. Removal of this layer decreases potential pasture production by about half.

CONTENTS

SECTION I. PRECIS FOLLOWING A.W.C. SUGGESTED FORMAT

TERMINATED PROJECT K/2/900 (B)

Grazing land productivity and stability

(a) Definition of the Project

This project commenced in 1957 and originally was part of W.R.T.F. Project 6 - Pasture Improvement and Forage Cropping. The broad aim was "to achieve a better understanding of the soil/water/plant/animal relationship in the sheep grazing and wool growing areas of Queensland". The practical end point was to produce a better continuity of supply of higher energy and/or protein forage for sheep, greater stability of sheep numbers and higher efficiency of wool production.

Project 6 was renumbered K/2/900 in 1973 and, in 1978, all studies associated with vegetation ecology of the sheep lands of western Queensland were amalgamated as Project K/2/900 (B) - Grazing Land Productivity and Stability.

(b) Objectives

The aim was to document long-term vegetation changes in the rangelands of southern and central-western Queensland and to define the conditions that lead to development of stands of desirable and undesirable perennial species composition. Data were obtained through intermittent monitoring of the perennial plant populations in areas either grazed by or protected from sheep and in areas subjected to opportunistic burning. Fields of investigation included:-

(i) Effects of thinning on productivity of two mulga scrub areas (established 1964/65)

(ii) Changes in the woody plant population along 64 km of permanently marked transects on two mulga properties (established 1965)

(iii) Botanical charges in 17 permanent exclosures covering areas of pasture degradation on the main land systems (established 1965)

(iv) Botanical and ground cover changes at 29 benchmark sites in well preserved condition on a variety of land systems (established 1972)

(v) Chemical control of woody weed species

(vi) Ecology and productivity of green turkey bush (*Eremophila gilesii*)

(vii) Moisture utilization of mulga trees and grasses in the mulga rangelands

(viii) Nutrient cycling in semi-arid woodlands

(ix) Effects of soil loss on pasture productivity in mulga areas

(x) Effects of fire on woody plants (particularly weeds) in areas subjected to opportunistic burning. (Superceded by project DAQ03P (K/2/1030))

(c) Outcome

Project K/2/900 (B) involved some 41 programmes from 1957 to 1983 (Appendix 1). These have been subdivided into four subsections, the main findings of which were:-

1. ECOLOGICAL STUDIES OF PLANT COMMUNITIES OF WESTERN QUEENSLAND

* The influence of mulga tree density on the yield of forage and of foliage for drought reserves was determined as a guide for mulga management.

* Forage yields decreased and foliage yields of mulga increased with increasing mulga tree density.

* Basal area of pasture species was higher under sparse tree densities, although drought conditions could destroy virtually all grass tussocks, irrespective of tree density.

* At one site, thinning of mulga greatly increased the regeneration of woody species including mulga and grey turkey bush. Green turkey bush numbers fluctuated widely, with germination favoured by cool season rains.

* Protection from grazing without additional treatment for more than 20 years did not result in major improvement in botanical composition. Woody plants, particularly Acacia and Eremophila species were favoured by protection from domestic stock.

* At one site, mitchell grass (Astrebla spp) deteriorated when ungrazed and its basal area decreased. White spear (Aristida leptopoda) and feathertop (Aristida latifolia) were not disadvantaged by exclosure.

* Feathertop density declined both with and without grazing at "Toorak" from 1963 to 1969, probably as a result of drought.

* Scalds and claypans did not return to productive states with removal of grazing animals alone.

* Species that warrant further ecophysiological investigation are:- Alternanthera nodiflora, Digitaria brownii, Sida spp., Panicum effusum, Enneapogon polyphyllus, Eriochloa spp., Erodium crinitum, Convolvulus erubescens, Chloris spp. (e.g. C. divaricata), Evolvulus alsinoides.

* Characteristics of growth, production and litter turnover of green turkey bush (Eremophila gilesii), a major woody weed of south-west Queensland, were determined. The plant is favoured in bud formation, flowering, fruit-set and germination by cool-season rains . Up to 5 x 10^6 fruits $ha^{-1}year^{-1}$ are produced in the highest density stands. Germination is highest between 15 and 25^{o}C, and severely inhibited at soil temperature with daytime maxima > 40^{o}C. Root growth of seedlings is greater than shoot growth, with a mean rate of 2.5cm/day. Seedlings can stand moisture stresses of >-100 atmospheres for considerable periods.

Control of green turkey bush can be obtained by ploughing, slashing at ground level or by use of many of the common herbicides.

* Population dynamics of woody species were followed in mulga communities representative of much of the sheep country west of the Warrego River from 1965 . Recordings of woody species from two 32 km long belt transects identified several species/site groups in which increasing elevation from flats to ridges seems to be the main factor consistent with community change. Species groups were small and represent small mosaics in which microtopography may be an important determinant of species distribution.

Populations of woody species have increased from 1965. A simulation study of future plant populations at "Humeburn" suggests that this trend is likely to continue.

* Germination of grass species (buffel and mulga mitchell) was inhibited by water soluble extracts from the leaves of green (Eremophila gilesii) and grey (E. bowmanii) turkey bush. A 50/50 soil extract from beneath the plants delayed and inhibited germination, while a similar extract from the inter-canopy area did not.

* Studies of lightly grazed ecological benchmarks investigated the possible role of rangeland condition and trend as a guide to management of western Queensland pastures. Results isolated potential dominant, sub-dominant and associated species on four main soil types - laterites, sandy red earths, rocky plateaux, and cracking clays. Key species lists have been established. The need for integrated long-term ecological research was highlighted.

* Studies of nutrient pool sizes in a mulga community, and a mallee (Eucalyptus socialis) community showed total phosphorus, available phosphorus and total nitrogen were similar in each community, with a pronounced concentration in surface layers.

The mulga community had higher levels of nitrogen in both living and dead tissues than did mallee. This suggested that nitrogen fixation by mulga was effective, but there was no nitrogen build-up in the soil profile.

Mulga was non-seasonal in its litter fall pattern while mallee was distinctly seasonal. Both mulga and mallee withdrew nitrogen and phosphorus from their leaves prior to abscission with both species equally conservative in their retention of phosphorus on their nutrient-poor soils.

Mulga, Cassia nemophila and mallee all responded to nitrogen and phosphorus applications in sand culture, but growth rates were much lower than for semi-arid grasses. Nevertheless, mulga grasslands were much less efficient in utilizing phosphorus than endemic woodlands and also required large amounts of nitrogen per unit of dry matter.

Grasses possess initial advantages in the establishment phase in semi-arid ecosystems through faster growth rates and mean phosphorus adsorbtion rates. In time, competing woody plants develop larger root systems which assist in nutrient adsorbtion and drought survival. The more efficient use of limited nutrients results in dominance by the woody plants.

* Seed production from mulga in south west Queensland is adequate for regeneration. Environmental conditions favour continual recruitment, with occasional mass germination. Animal management is important in the survival of these seedlings.

2. CONTROL OF WOODY WEED SPECIES BY CHEMICAL AND OTHER METHODS

* Control of woody weeds in central- and south-western Queensland can be achieved by commonly available chemicals, though this is only economical in special situations. A native wingless grasshopper was investigated as a possible control measure for Eremophila gilesii, but was found to be unsuited for widespread use because of limited population build up.

3. MOISTURE RELATIONS IN SCRUB COMMUNITIES

Large mulga trees intercepted a higher proportion of rainfall than small trees, but the proportion of throughfall and stemflow decreased. Volume of stemflow increased with larger tree size. Interception decreased with increasing wind speed. Throughfall increased with increasing intensity of rainfall up to 6mm aggregate , but stemflow and the interception component were not affected. Infiltration was highest close to the trunk.

* Water use by vegetation was lower on totally cleared sites than on areas supporting 40, 160, 640, and 3600 trees ha^{-1}. Within 70 days of total soil recharge, soil moisture content was at or below wilting point in the entire root zone. Evapotranspiration rate ranged from 0.3mm day^{-1} with limiting soil moisture to 7.6mm day^{-1} following effective rainfall.

Thinning of mulga communities increased light intensity at ground level and increased the quantity of rain available for soil moisture recharge.

* Both mulga and the predominant grass (Aristida spp) had high densities of roots in the first 30 cm of soil allowing them to use light rainfall. As well, both had roots penetrating to >135 cm, giving access to moisture from depths to aid drought survival.

* Growth rates of wood and leaf in mulga varied considerably.

* Both mulga and grass growth was affected by moisture stress and soil fertility. Mulga seedlings were capable of surviving on 12.5 mm of rain per month, though germination usually required 37.5 mm or more.

* Surface runoff was greatest from hard mulga and residual land zones than from soft mulga. Even small falls (<15mm) produced runoff equivalent to 50%. Grass tussocks decreased the number of rainfall events that generated runoff. The maintenance of a basal cover of perennial plants of more than 2% is considered essential to reduce loss of surface soil and nutrients

4. MISCELLANEOUS STUDIES

* Low-lying areas of mitchell grass and those with a low degree of slope supported only annual growth. The percentage of available soil moisture varied from 22% in a healthy area to 15% in a denuded area.

* Mulga soils have a concentration of nutrients in the upper 5 cm of soil. Removal of this layer decreases potential pasture production by about half.

(d) Implementation/Extension

Information obtained from this project has vastly improved the knowledge of how the plant communities of western Queensland function. It has highlighted the productivity relationship between woody vegetation and ground storey plants. It has drawn attention to the build-up in the woody weed populations which threaten productivity. The role of chemicals in control of these species is effective but uneconomical. The need for alternative control measures (e.g. fire) has been highlighted.

Results obtained from this project, combined with those from other research projects undertaken in the area, have allowed the development of management strategies for the region.

Pressland (1976) addressed the effects of removal of mulga on rangeland stability. Even ten years after thinning, ground storey vegetation is still in a state of flux. Management can markedly influence pasture composition and mulga regeneration. Poor rangeland management may lead to reductions in basal area sufficient to reduce productivity and accelerate degeneration through soil and nutrient losses in run-off water. Mills (1981) discussed land degradation in the mulga lands of far south-west Queensland in relation to the extended drought periods which occur (Figure 2). Pressland (1981, 1984) found that stocking rates in mulga country were similar to those in mitchell grass country, despite much larger levels of pasture biomass in the latter. Both he and Mills (1981) developed the theme that maintenance of stock numbers on mulga country during extended dry periods, and restocking too rapidly at the end of a drought is biologically unsound. An alternative approach outlines the need for financial incentives to encourage sound biological practices and for government assistance in the search for, and finance of, additional areas for small landholders.

Burrows (1979) concluded that the central requirements for sound vegetation management in Queensland's semi-arid sheeplands are, firstly, a realistic appraisal of the environment, and secondly, enterprises sufficiently large to favour conservative stocking policies (legislatively enforced if necessary). Inherent in this concept is the ability to lighten grazing pressures (at times of nutritional stress) and to increase them by adjustment of paddock size (for shrub control). In the latter case the choice between winter and summer grazing may also be important. Present knowledge of the autecology and reaction to grazing of the vast majority of plants in these ecosystems is poor, and until this situation can be improved, under- rather than over-utilization should be encouraged.

Burrows (1980) listed management principles that apply to animal production in the dry tropics of Queensland:-

(i) Environmental determinants of animal production.

* Variability of amount and effectiveness of rainfall is the primary factor limiting pasture growth and, hence, animal production.

* Ninety percent of potential grass production in mulga pastures occurs in the October-March period.

* Mitchell grass soils are inherently fertile while mulga soils are quite infertile, being characterized by a strongly acid profile, low nutrient availability (notably phosphorus) and surface sealing which contributes to significant rainfall run-off.

* Woody plants tend to dominate rangelands, especially on infertile soils. As the environment becomes harsher, shrubs will tend to dominate rather than trees, where the physiologically more efficient life-form of the shrub is needed for persistence. (Control of problem woody species in western Queensland has been summarised by Scanlan and Pressland (1984)).

* In induced grasslands or savannah, there is an inverse curvilinear relationship between woody plant density and pasture yield. Unlike higher rainfall regions, many of the trees and shrubs of the inland are important sources of browse for domestic animals.

* Surface water availability is generally not a problem in mitchell grass and mulga systems (in most seasons) and the underlying artesian basin ensures relatively even use of these rangelands.

(ii) Managerial determinants of animal production.

* Pasture stability and animal productivity on semi-arid rangelands are affected by many factors such as soils, vegetation type, rainfall, stocking pressures and industry economics. Of these factors the most readily manipulated by the grazier are concerned with his stock e. g. types of animals being grazed, stocking pressures and time of shearing.

* Stock numbers should be adjusted to the feed available. In practice, this means that carrying capacity is determined largely by the numbers that can be carried safely in poor seasons.

* Animal production, as opposed to liveweight maintenance, is influenced largely by the availability and accessibility of broad-leaved plants ("nutrient accumulators") in the pasture.

* The need to improve animal productivity has to be balanced against the need to promote stability through the maintenance of a high proportion of perennial grass in the pasture. There is clear evidence that interseasonal variation is markedly greater where the vegetation consists mostly of annual species. For this reason, along with the difficulty of establishing grass species on infertile soils, basal area will generally override composition as the principal determinant of grassland condition.

* Utilization levels should be adjusted so that consumption does not exceed about 20 percent of end-of-summer production in mulga grasslands and 40 percent in mitchell grasslands. In practice stocking levels should be such that 12 months after grass growing rain has fallen there is still a good coverage of stubble on the pasture. There is little evidence that rotational or other grazing systems in Australian rangelands improve vegetative cover or animal production over continuous grazing systems. By corollary, as far as it is practical, animals should be segregated within herd or flock structures but allowed freedom of movement within uniform land units.

* The minimum requirement of animal management is disease and parasite control. Mineral supplementation is beneficial in certain situations but it is not a panacea to nutritional stress in mulga and Mitchell grass systems.

These management principles have been further discussed in Harrington et al. (1984), Orr and Holmes (1984), Pressland (1984, 1985), Wilson et al. (1984) and Sullivan et al. (1985). They have been extended to the grazing, scientific, and land administration communities, both in western Queensland and other states, whenever opportunities and means have arisen.

(e) Further Work

This project has highlighted the continual increase in woody weeds and the need for economical control measures. Projects developed, at least in part, from this include:-

(i) Susceptibility of woody weeds to fire and impact of fire on ground flora composition and production (K/2/1030).

(ii) An assessment of the cost of land degradation to the wool industry in south-west Queensland (K/2/1037)

(iii) Western mulga region land survey (Queensland Department of Primary Industries and Queensland Department of Lands)

(iv) Submissions to the New South Wales Joint Parliamentary Enquiry into the Western Division.

(v) Submissions to National Soil Conservation Programme for studies on the effects of management on rates of loss of soil and water run-off

(vi) Submissions to the Wool Research Trust Fund on studies of reseeding and rehabilitation of degraded mulga areas in south-west Queensland including the investigation of the use of native species

(vii) Submissions to the Wool Research Trust Fund on studies of the role of complementary grazing by sheep and goats in improving the stability and productivity of rangelands

(viii) Submissions to the Wool Research Trust Fund on the development of property management models for western Queensland

(f) Cost

Total cost to the Trust Fund was about $303 000. This project was initially part of W.R.T.F. Project 6, and was not costed separately until it became K/2/900 (B). The total expenditure represents about 9.5% of the W.R.T.F. Production Research expenditure in Queensland since 1957, in an area that includes some 65% of the sheep population of Queensland

(g) PUBLICATIONS ARISING FROM, OR ASSOCIATED WITH, THE PROJECT

ABBREVIATIONS FOR TYPE OF PUBLICATION:

R = Research Paper T = Thesis C = Conference Paper
REP = Report E = Extension Article B = Book
M = Miscellaneous Publication

ALLSOPP, P.G. (1976a). Biological control of green turkey bush. Qd Agric. J. 102: 433-434. (E)

ALLSOPP, P.G. (1976b). Studies in the ecology of *Monistria discrepans* (Walker) (Orthoptera: Pyrgomorphidae) in southern Queensland. M.Agr.Sc. Thesis, University of Queensland. (T)

ALLSOPP, P.G. (1977). Biology and capacity for increase of *Monistria discrepans* (Walker) (Orthoptera: Phygomorphidae) in the laboratory. J. Aust. Ento. Soc. 16: 207-213. (R)

ALLSOPP, P.G. (1978). Seasonal history, hosts and natural enemies of *Monistria discrepans* (Walker) (Orthoptera: Pyrgomorphidae) in South-west Queensland. J. Aust. Ento. Soc. 17: 65-73. (R)

BATIANOFF, G.N and BURROWS, W.H. (1973). Studies in the dynamics and control of woody weeds in semi-arid Queensland. II. *Cassia nemophila* and *C. artemisiodes*. Qd J. Agric. Anim. Sci. 30: 65-71. (R)

BEALE, I.F. (1969). Construction of a frost free plant house. Qd J. Agric. Anim. Sci. 26: 553-563. (R)

BEALE, I.F. (1970). Influence of mulga (*Acacia aneura* F. Muell.) tree density on leaf fall and herbage production. Proc. 3rd Aust. Arid Zone Conf. Broken Hill pp 6.26-6.28. (C)

BEALE, I.F. (1971). The effect of thinning on the productivity of two mulga (*Acacia aneura* F. Muell.) communities in south western Queensland. M.Agr.Sc. Thesis, Univ. Qd. (T)

BEALE, I.F. (1973). Tree density effects on yields of herbage and tree components in south west Queensland mulga (*Acacia aneura* F. Muell.) scrub. Trop. Grasslds 7: 135-142. (R)

BEALE, I.F. and BURROWS, W.H. (1968). Productivity of mulga scrubs in south west Queensland. Aust. Grassland Congr. Section 2b: 24-25. (C)

BEALE, I.F. and BURROWS, W.H. (1970). Density of native grasses in mulga communities of south west Queensland. Proc. 3rd Aust. Arid Zone Conf., Broken Hill pp 6.27-6.28. (C)

BEALE, I.F., ORR, D.M. and MILLS, J.R. (1985). Pastoral impact on the ecosystem. Proc. The Mulga Lands Symp., Roy. Soc. Qd, Brisbane. (C) (in press).

BURROWS, W.H. (1965). Woody weeds on run-on and run-off areas in south west Queensland. Proc. 2nd Aust. Arid Zone Conf. Alice Springs. pp C16-17. (C)

BURROWS, W.H. (1970). Intensify studies on natural pasture. In: "Tropical Pasture Manual" Ad., Country Life Newspaper, Brisbane. (E)

BURROWS, W.H. (1971). Studies in the ecology and control of green turkey bush (Eremophila gilesii F. Muell.) in south west Queensland. M.Agr.Sc. Thesis, Univ. Qd. (T)

BURROWS, W.H. (1972). Productivity of an arid zone shrub (Eremophila gilesii) community in south west Queensland. Aust. J. Bot. 20: 317-29. (R)

BURROWS, W.H. (1973a). Regeneration and spatial patterns of Acacia aneura in south west Queensland. Trop. Grasslds 7: 57 - 68. (R)

BURROWS, W.H. (1973b). Studies in the dynamics and control of woody weeds in semi arid Queensland. I. Eremophila gilesii. Qd J. Agric. Anim. Sci. 30: 57-64. (R)

BURROWS, W.H. (1974a). A study of the phenology and germination of Eremophila gilesii in semi arid Queensland. In: "Plant morphogenesis as the basis for scientific management of rangelands." Proc. U.S. - Australian Workshop, Berkeley. U.S.D.A. Miscl. Publ. No. 1271 pp 150-59. (C)

BURROWS, W.H. (1974b). Trees and shrubs in mulga lands. Qd Agric. J. 100: 322-31. (E)

BURROWS W.H. (1976a) Condition assessment in woodland/shrubland. In: "Native pasture methods workshop". Qd Dept Prim. Ind. Mimeo. (C)

BURROWS, W.H. (1976b). Aspects of nutrient cycling in semi-arid mallee and mulga communities. Ph.D. Thesis, Aust. Nat. Univ. (T)

BURROWS, W.H. (1979). Vegetation management decisions in Queensland's semi arid sheeplands. In: "Rangeland ecosystem evaluation and management" (Ed. Howes, K.M.S.). Aust. Rangel. Soc., Perth, pp. 202-218. (R)

BURROWS, W.H. (1980). Range management in the dry tropics with special reference to Queensland. Trop. Grasslds 14: 281-287. (R)

BURROWS, W.H. (1985). Potential ecosystem productivity. Proc. Mulga Lands Symp., Roy. Soc. Qd., Brisbane. (C) (in press)

BURROWS, W.H., CULL, J.K. and EBERSOHN, J.P. (1966). Water redistribution for increasing pasture and forage production: A review. Arid Zone Newsletter pp 78-85. (REP)

BURROWS, W.H. and BEALE, I.F. (1969). Structure and association in the mulga (Acacia aneura) lands of south western Queensland. Aust. J. Bot. 17: 539-552. (R)

BURROWS, W.H. and BEALE, I.F. (1970). Dimension and production relations of mulga (Acacia aneura F. Muell.) trees in semi arid Queensland. Proc. 11th Intl Grassld Congr. Surfers Paradise, Australia. pp. 33-35. (R)

BURROWS W.H. and BEALE I.F. (1976) Techniques for studying vegetation in the semi-arid pastoral zone. In: "Native pasture methods workshop". Qd Dept Prim. Ind. Mimeo. (C)

BURROWS, W.H., BEALE, I.F., SILCOCK, R.G., and PRESSLAND, A.J. (1985). Prediction of tree and shrub population changes in a semi-arid woodland. In: "Ecology and management of the world's savannas". (Eds Tothill, J.C. and Mott, J.J.). Aust. Acad. Sci, Canberra.

CAMPBELL, C.B. (1971). Gidgee development. Qd Agric. J. 97: 346-52. (E)

CHRISTIE, E.K. (1976a) Integration of ecosystem processes in semi-arid Environments. In: "Native pasture methods workshop". Qd Dept Prim. Ind. Mimeo. (C)

CHRISTIE, E.K. (1976b) Condition assessment of semi arid grassland. In: "Native pasture methods workshop" Qd Dept. Prim. Ind. Mimeo. (C)

CHRISTIE, E.K. (1976c). Condition assessment of an infertile range grassland based on site production potential. Aust. Arid Zone Res. Conf., Kalgoorlie. 4:25-28. (C)

CHRISTIE, E.K. (1978). Herbage condition assessment of an infertile semi arid grassland based on site production potential. Aust. Rangel. J. 1: 87-94. (R)

EBERSOHN, J.P. (1963). Mulga scrub lands of the south west. Proc. West. Qd Agrostol. Conf., Charleville. Paper No. 2. (C)

EBERSOHN, J.P. (1967). Some plants and plant communities of the Australian semi-arid zone: An ecological appraisal of their nature, distribution and dynamics. Proc. Sheep and Wool Refresher Course 1967, Aust. Wool Board Mimeo. (R)

EBERSOHN, J.P. (1970a). Vegetation resources of arid Australia. Proc. 3rd Aust. Arid Zone Res. Conf., Broken Hill, pp 6.1-6.11. (C)

EBERSOHN, J.P. (1972a). Native communities in Queensland's sheep country. In: "Plants for sheep in Australia." (Eds Leigh, J.H. and Noble, J.C.) Angus and Robertson, Sydney. (B)

EBERSOHN, J.P. (1972b). Some features of mulga (*Acacia aneura* F. Muell.) and mulga lands. Qd Dept Prim. Ind. Mimeo. (M)

EBERSOHN, J.P., and LUCAS, P. (1965). Trees and soil nutrients in south western Queensland. Qd J. Agric. Anim. Sci. 22: 431. (R)

HARRINGTON, G.N., MILLS, D.M.D., PRESSLAND A.J. and HODGKINSON, K.C. (1984). Management of semi arid woodland ecosystems. In: "Management of Australia's rangelands". (Eds Harrington, G.N.,Wilson, A.D. and Young, M.D.). CSIRO, Melbourne. (B)

JOHNSON, R.W. and BURROWS, W.H. (1981). Acacia tall open forests, woodlands and shrublands. In: "Australian vegetation". (Ed Groves, R.H.). Cambridge Univ. Press: London. (B)

MILLS, J.R. (1981). Land degradation and drought relief measures in the mulga lands of western Queensland. Proc. 3rd Bienn. Conf., Aust. Rangel. Soc. Alice Springs. (C)

MILLS, J.R. (1982b). Pastoralism in south west Queensland. Proc. "Focus on Australia's arid lands", Broken Hill. Aust. Cons. Found., Melbourne (C)

MILLS, J.R. (1984). Extent of land degradation in the Paroo region of south west Queensland - a preliminary estimate. Proc. 2nd Intl Rangel. Congr., Adelaide. (C)

MILLS, J.R. (1985). Degradation and rehabilitation of the mulga ecosystem. Proc. The Mulga Lands Symp., Roy. Soc. Qd, Brisbane. (C)

MURRAY, R.M. and PURCELL, D.L. (1967). Pastures in the sheep country. Qd Agric. J. 93: 284-293. (E)

ORR, D.M. (1975) Central Western Queensland. In "Native pastures resources of Queensland". Qd Dept Prim. Ind. Emerald. Mimeo. (C)

ORR, D.M. (1981). Changes in the quantitative floristics in some Astrebla spp. (mitchell grass) communities in south western Queensland in relation to trends in seasonal rainfall. Aust. J. Bot. 29: 533-45. (R)

ORR, D.M. (1986) Factors affecting the vegetation dynamics in Astrebla spp. grasslands. Ph. D. Thesis, Univ. of Qd. (Submitted). (T)

ORR, D.M. and HOLMES, W.E. (1984) Mitchell grasslands. In: "Management of Australia's rangelands". (Eds Harrington, G.N., Wilson, A.D. and Young, M.D.). CSIRO, Melbourne. (B)

ORR, D.M. and EVENSON, C.J. (1985) Influence of rainfall and grazing on the vegetation dynamics of a semi-arid grassland in south west Queensland. In: "Ecology and management of the world's savannas". (Eds Tothill, J.C. and Mott, J.J.). Aust. Acad. Sci., Canberra. (C)

PRESSLAND, A.J. (1972). Micrometeorological observations in a desert woodland. (Acacia aneura F. Muell.) in south western Queensland. M.Sc. Prelim. Thesis, Univ. New England. (T)

PRESSLAND, A.J. (1973a). Soil moisture distribution and evapotranspiration of a mulga (Acacia aneura F. Muell.) scrubland in south western Queensland. In "Studies of the Australian Arid Zone Symposium III - Water in Rangelands", Alice Springs, October 15-18, 1973. (C)

PRESSLAND, A.J. (1973b). Rainfall partitioning by an arid woodland (Acacia aneura F. Muell.) in south western Queensland. Aust. J. Bot. 21: 235-45. (R)

PRESSLAND, A.J. (1974). Redistribution of precipitation, water use and productivity of thinned mulga (Acacia aneura F. Muell.) communities in south western Qd. M.Sc. Thesis, Univ. New England. (T)

PRESSLAND, A.J. (1975). Productivity and management of mulga in south-western Queensland in relation to tree structure and density. Aust. J. Bot. 25: 965-76. (R)

PRESSLAND, A.J. (1976a). Possible effects of removal of mulga on rangeland stability in south western Queensland. Aust. Rangel. J. 1: 24-30. (R)

PRESSLAND, A.J. (1976b). Effect of stand density on water use of mulga (Acacia aneura F. Muell.) woodlands in south western Queensland. Aust. J. Bot. 24: 177-91. (R)

PRESSLAND, A.J. (1976c). Soil moisture redistribution as affected by throughfall and stem flow in an arid zone shrub community. Aust. J. Bot. 24: 641-649. (R)

PRESSLAND, A.J. (1981a). Drought and the mulga lands of Queensland. Proc. 3rd Bienn. Conf., Aust. Rangel. Soc., Alice Springs, pp 163-173. (C)

PRESSLAND, A.J. (1981b). Woody weeds in Australian Rangelands: Is prevention easier then cure? Proc. 6th Aust. Weeds Conf., Gold Coast, 1981. pp 169-174. (C)

PRESSLAND, A.J. (1981c). Runoff and the ameliorating effect of plant cover. Proc. 3rd Bienn. Conf. Aust. Rangel. Soc., Alice Springs, 1981. pp. 49-52. (C)

PRESSLAND A.J. (1983) Land degradation and erosion in western Queensland. Proc. Qd Dept Prim. Ind. - Lands Dept. Wshop, Charleville Pastoral Lab. Mimeo. (C)

PRESSLAND, A.J. (1984a) Vegetation dynamics in semi arid woodland ecosystems. Proc. 2nd Intl Rangel Congr., Adelaide, May 1984. (C)

PRESSLAND, A.J. (1984b) A review of the productivity and management of western Queensland's rangelands. Aust. Rangel. J. 6: 28 - 45. (R)

PRESSLAND, A.J. and LEHANE, K.J. (1977). Runoff from natural and simulated rainfall in the mulga communities of south western Queensland. Proc. 2nd Bienn. Conf. Aust. Rangel. Soc., Broken Hill, July 8, 1977 pp 147-160. (C)

PRESSLAND, A.J. and LEHANE, K.J. (1980). Run-off from natural and simulated rainfall in the mulga communities of south western Queensland. Aust. Rangel. J. 2: 217-221. (R)

PRITCHARD, D.A. and MILLS, J.R. (1985). Drought and its significance. Proc. Mulga Lands Symp., Roy. Soc. Qd., Brisbane. (C)

PURCELL, D.L. (1963a). Gidgee scrub lands. Proc. West. Qd. Agrostol. Conf. Charleville (Mimeo). (C)

PURCELL, D.L. (1963b). The "desert" country. Proc. West. Qd Agrostol. Conf. Charleville (Mimeo). (C)

PURCELL, D.L. (1963c). The mitchell grass association of central western Queensland. Proc. West. Qd. Agrostol. Conf. Charleville (Mimeo). (C)

PURCELL, D.L. (1963d). Brigalow lands of the central west. Proc. West. Qd Agrostol. Conf. Charleville (Mimeo). (C)

ROBERTS, B.R. (1972). Ecological studies on pasture condition in semi-arid Queensland. Qd Dept. Prim. Ind. Mimeo. (REP)

ROBERTS, B.R. (1973). The mulga lands symposium: An evaluation. Trop. Grasslds 7: 169-170. (C)

ROBERTS, B.R. (1975a) The necessity for objectivity of grazing land condition assessment. In "Resource management in south west Queensland". Qd Dept Prim. Ind. Mimeo. (C)

ROBERTS, B.R. (1975b) Review of a grazing land condition "benchmark" study in south west Qd. In "Resource management in south west Queensland". Qd Dept Prim. Ind. Mimeo. (C)

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: 743-752. (R)

SCANLAN, J.C. and PRESSLAND, A.J. (1984). "Major woody weeds of western Queensland and their control". Qd Dept Prim. Ind. QI84017. (E)

SCATTINI, W.J., ORR, D.M., MILLER, C.P., HOLMES, W.E. and HALL, T.J. (1985). Managing native grassland. In "Native pastures in Queensland" (Eds. Burrows, W.H. and Scanlan, J.C.). Qd Dept Prim. Ind. (In press). (B)

SILCOCK, R.G. (1981). Are drought relief schemes desirable? Proc. 3rd Bienn. Conf. Aust. Rangel. Soc , Alice Springs, p. 163. (C)

SILCOCK, R.G. (1985). Agriculture, impact of clearing and pasture introduction. Proc. Mulga Lands Symp., Roy. Soc. Qd., Brisbane. (C)

SMITH, F.T., CROWTHER, D.E., BOWLY, P.S., EVENSON, C.J., LEHANE, K.J., BEALE, I.F., ROBERTS, B.R. AND BURROWS, W.H. (1984). A photographic record of vegetation changes in two semi-arid woodlands. In: "Ecology and management of the world's savannas". (Eds Tothill, J.C. and Mott, J.J.). Aust. Acad. Sci., Canberra. (R)

SULLIVAN, M.T. (1984) Use of woody weed monitoring sites. Proc. Woody Weed Control Wshop, Gympie. The Weed Soc. Qd. Part 4. (C)

SULLIVAN, M.T., DAY, J.R., CLARKE, M.R. and DUNLOP, L.B. (1985). Management to sustain animal productivity and stability in the mulga zone. Proc. Mulga Symp., Roy. Soc. Qd., Brisbane. (C)

WESTON, E.J. and MOIR, K.W. (1969). Grazing preferences of sheep and nutritive value of plant components in a mitchell grass association in north-west Queensland. Qd J. Agric. Anim. Sci. 26: 639-650. (R)

WILSON, A.D., HARRINGTON, G.N. AND BEALE, I.F. (1984) Grazing Management. In "Management of Australia's Rangelands" (Eds Harrington, G.N., Wilson, A.D. and Young, M.D.). CSIRO, Melbourne. (B)

SECTION II

DETAILED PROJECT REPORT

ACKNOWLEDGEMENTS

Since this project was commenced in 1957 by Agriculture Branch, Queensland Department of Primary Industries, it has involved a number of centres and a larger number of staff, both graduate and technical. In this report, acknowledgement has been made of those who contributed significantly to the research programme. Dr J.P. Ebersohn provided ideas and inspiration that led to the establishment of the Charleville Pastoral Laboratory, which has established a wide reputation as a centre for arid zone research. He was also responsible for overseeing the programme in its period of expansion.

The financial and moral support of the Australian Wool Corporation and of senior officers of the Queensland Department of Primary Industries has ensured that the team effort at this Laboratory continues. The co-operation of other Branches in Q.D.P.I. is also acknowledged. These include Agricultural Chemistry Branch, Beef Cattle Husbandry Branch, Biochemistry Branch, Biometry Branch, Botany Branch, Clerical and General Branch, Economic Services Branch, Entomology Branch, Extension Services Branch, Land Resources Branch, Plant and Animal Pathology Branches, Sheep and Wool Branch, Standards Branch, Veterinary Services Branch and The Animal Research Institute, Yeerongpilly.

Numerous experiments were conducted during the period covered by this report. For details of them a number of sources have been used, the main ones being:-

(i) Agrostology Technical Annual Reports (QDPI)
(Pasture Agronomy Technical Annual Report from 1982 onwards)

(ii) Published papers

(iii) Departmental records

(iv) "Review of Research in western Queensland", South - Western Research Committee, QDPI Mimeo. 1975.

(v) "A handbook of research by the Charleville Pastoral Laboratory", Qd. Dept Prim. Ind. Mimeo., 1980

Project summaries have been used where applicable. The authors , who may not have been identified and may not be cited in the text, are acknowledged for their contributions.

HISTORY OF K/2/900 (B) -

GRAZING LAND PRODUCTIVITY AND STABILITY

Project commenced: 1957 Terminated: June 1985

Locations: The main sites in this project were Charleville, and Blackall, with a smaller site located at "Toorak" via Julia Creek (Figure 1).

Staff involved in Project K/2/900 (B):

(i) Officers-in-Charge:

(Charleville)	1957 - 1962	Dr L.R. Humphreys, Mr. R.G. Wilson
	1962 - 1964	Dr J.P. Ebersohn
	1965 - 1973	Dr W.H. Burrows
	1973 - 1974	Dr A.J. Pressland
	1974 - 1975	Dr B.R. Roberts
	1976 - 1980	Dr W.H. Burrows
	1980 - 1986	Dr I.F. Beale
(Blackall)	1961 - 1965	Mr D.L. Purcell, Mr J.K. Cull
	1966 - 1969	Mr G.R. Lee
	1970 - 1972	Mr T.W.G. Graham
	1972 - 1984	Mr D.M. Orr
(Toorak)	1961 - 1967	Mr E.J. Weston
	1967 - 1968	Mr J. Peart

(ii) Graduate Staff T.E. Telford, Dr E.K. Christie, Dr R.G. Silcock, J. Peart, Dr R.F. Brown, M.T. Sullivan, Janelle R. Day, J.F.S. O'Donnell.

(iii) Technicians Flora T. Smith, G.N. Batianoff, P.J. Rowen, B.J. Caffery, R.G. McIntyre, Lyn (Corbett) Williams, C.L. Palmer, K.J. Lehane, M.F. Olsen, D.F. Edwards, D.E. Crowther, P.S. Bowly, C.J. Evenson, J. Dixon, D.C. Cowan, Jennifer Mander - Jones, K. Rundle, D.L. Shirley, P. McIntyre, J.Rickmann.

Allocation from W.R.T.F.: Approximately $303 000 (not costed separately prior to 1978)

Allocation from Q.D.P.I.: Approximately $822 000. (Most of this was for salaries and support staff)

WESTERN QUEENSLAND

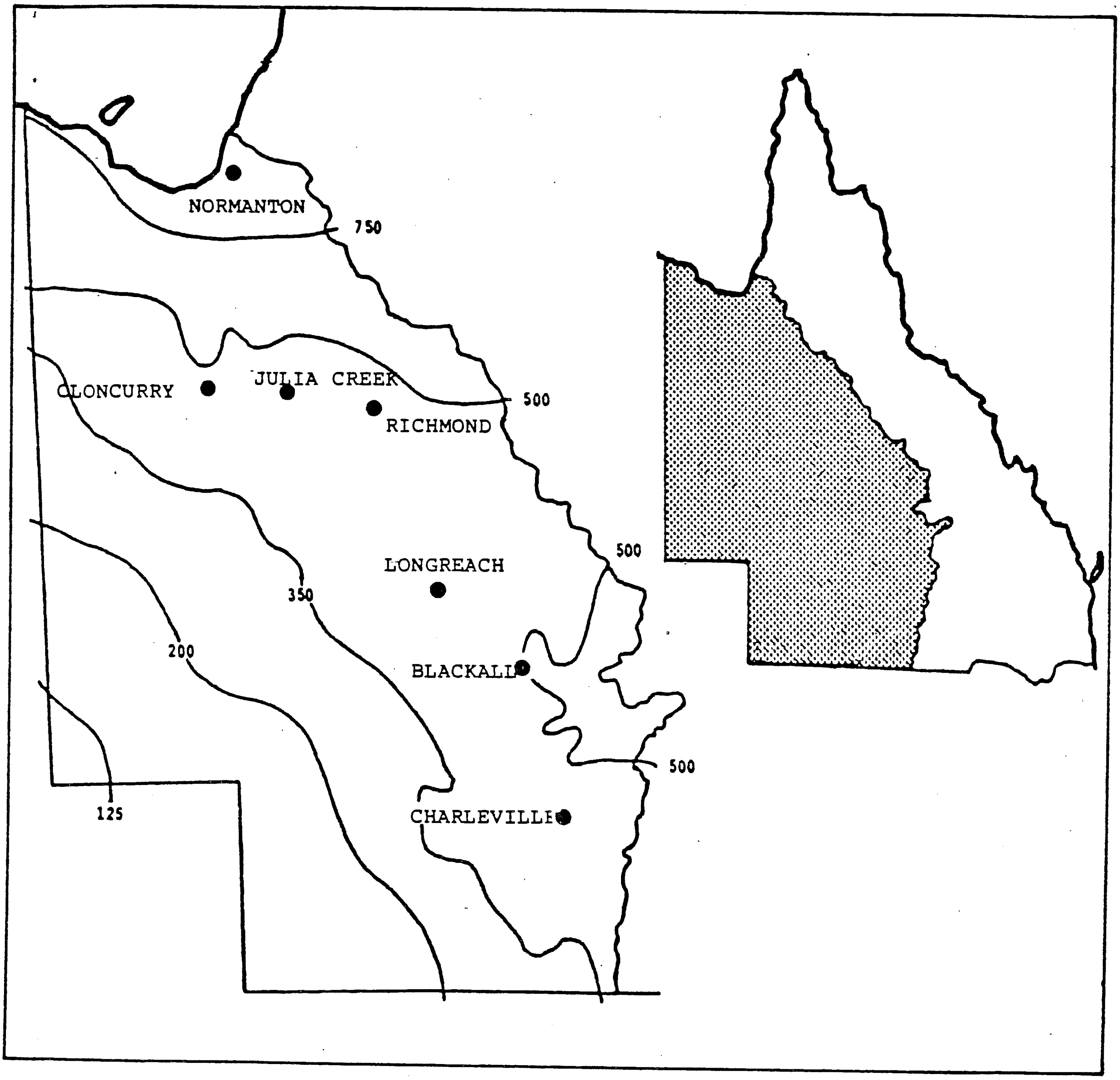


Figure 1: Location of main towns in Western Queensland.

A. INTRODUCTION

This project had its beginnings as part of a larger project (W.R.T.F. Project 6 - Pasture Improvement and Forage Cropping). In 1973, this was re-numbered to K/2/900 and in 1978 sub-divided into five sections :-

K/2/900	(A)	Plant Introduction, Evaluation and Establishment of Introduced and Native Pasture Species (Report 1984)
K/2/900	(B)	Grazing Land Productivity and Stability (Report 1986)
K/2/900	(C)	Animal - Plant Interactions in Native Pastures of Western Queensland (Report 1986)
K/2/900	(D)	Adaptation and Productivity of Annual Medics (Report 1985 /86)
K/2/900	(E)	Evaluation of Shallow Water Storage Cropping in North West Queensland (Report 1981)

The main research areas involved in K/2/900 (B) are :-

(i) Ecological studies of plant communities in western Queensland

(ii) Control of woody species by chemical and other methods

(iii) Moisture relations in scrub communities

(iv) Miscellaneous studies

B. DESCRIPTION OF THE AREA

The major centres involved in this project were Charleville, Blackall, and "Toorak" via Julia Creek (Figure 1).

Climatic features (Table 1) can be summarized as :-

* Predominantly summer rainfall, with an increasing winter component towards the south
* High summer temperatures
* Increasing incidence of frost in winter towards the south
* High evaporation rates
* Frequent incidence of drought (Figure 2).

The major vegetation types are the mitchell grasslands on fertile grey-brown cracking clay soils and the mulga scrublands on infertile red earths.

Table 1. Seasonal rainfall and temperature at selected centres (Data from Bureau of Meteorology, Melbourne) (Pressland 1984 b)

Location	Rainfall (mm) Summer (Oct-Mar)	Winter (Apr-Sept)	Annual	Temperature (°C) Summer Max	Summer Min	Winter Max	Winter Min
Longreach	327	115	442	36.1	20.7	26.8	10.7
Barcaldine	364	150	514	34.5	20.2	26.1	11.5
Blackall	382	157	539	34.9	20.1	25.8	10.3
Tambo	351	163	514	33.2	17.6	24.4	7.0
Charleville	297	154	451	34.4	19.0	24.1	7.8
Quilpie	236	108	344	34.3	20.5	23.6	9.5
Cunnamulla	188	129	317	33.7	19.2	22.5	8.8
Thargomindah	176	92	268	34.1	20.7	22.6	9.4

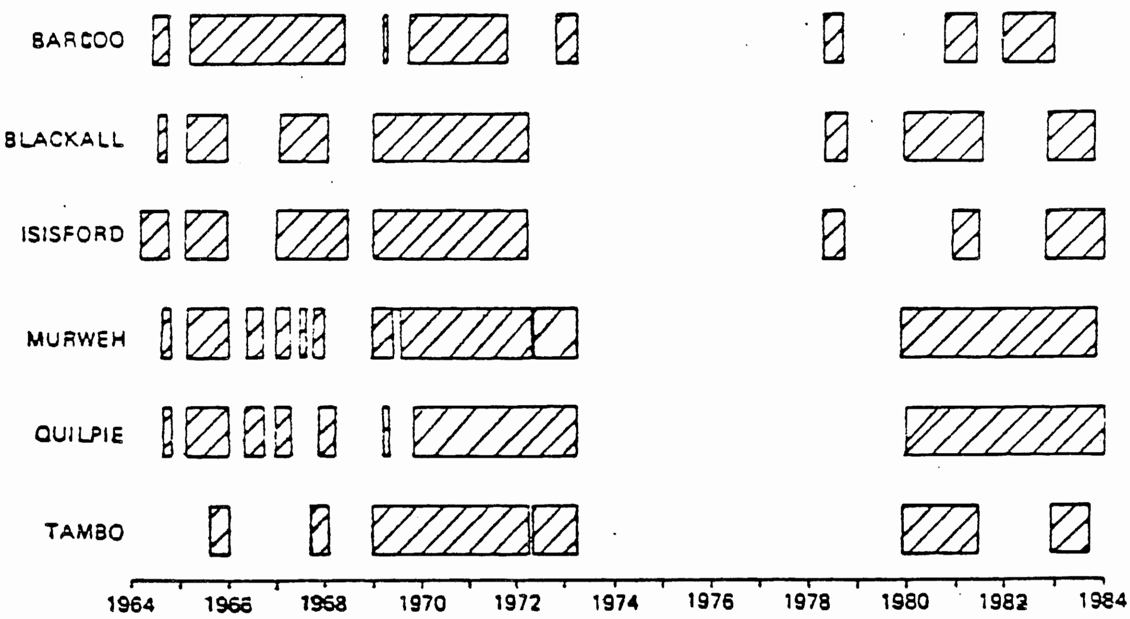


Figure 2: Declared drought periods 1964-1983 for 6 western Queensland shires. (Pressland 1984b).

C. PROJECT LIST, DESCRIPTIONS AND RESULTS

Project K/2/900 (B) involved some 41 separate experimental programmes (Appendix 1). The review of these programmes has been conducted by the use of summaries from final reports and publications where they are available. Other projects that have not previously been reported in detail are given more extensive coverage.

1 ECOLOGICAL STUDIES OF PLANT COMMUNITIES OF WESTERN QUEENSLAND

There is ample literature detailing the degradation which can occur where excessive numbers of domestic animals or inappropriate management have been imposed on semi-arid grazing lands (Condon et al. 1969; Newman and Condon 1969; Heady 1975). Strong evidence that degradation was occurring in Australia dated back to 1901 when the Western Land Inquiry was held in New South Wales. However, well documented evidence of just what changes were occurring was scarce, especially information to distinguish climatic droughts from man induced feed shortages.

In south-west Queensland, for a long time to come, if not for all time, the grazing industry will depend mainly on the native vegetation for the production of wool and beef. Drought, grazing and fire are the principal factors influencing stability of the vegetation and hence the welfare of the grazing industry. Uncertainty exists as to which effects are attributable to which factor, factors or combination of factors. A prerequisite to reclamation and the subsequent improved management or manipulation of native pastures is to know the pattern of seral development (or degradation) of whole communities and the nature and productive capacity of the various stages which may be reached under specific defoliation regimes.

Therefore, collection of thisinformation was undertaken.

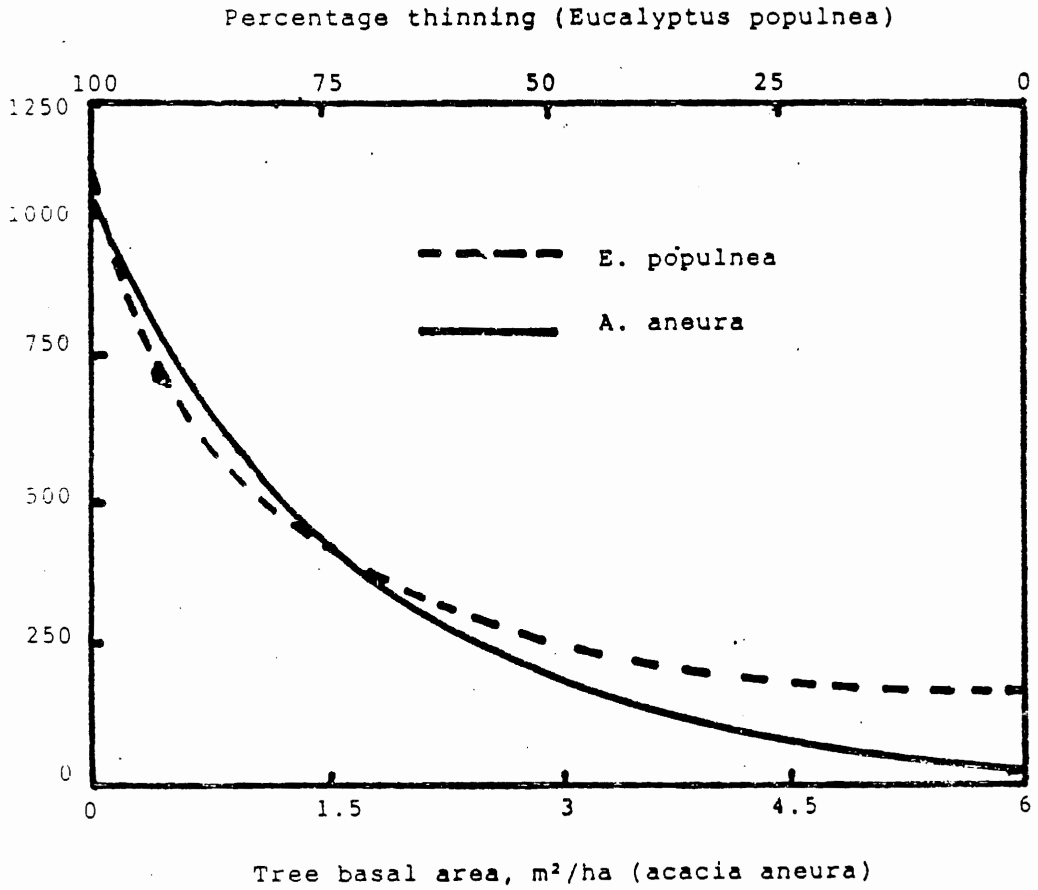
Productivity of mulga scrubs - Mulga density trials Boatman (CLE-P1-WR) and Monamby (CLE-P6-WR).

Mulga (*Acacia aneura*) is the predominant tree on about 20 million hectares of south west Queensland. It varies in density from open grassy savannas to thick scrubs with little ground cover. Its use as a drought supplement required knowledge of the optimum tree density for production of both foliage for drought fodder and ground-storey vegetation. Studies commenced at two sites in 1964/65 where scrubs were thinned to 40, 160 and 640 trees per hectare.

Leaf yields were influenced by tree numbers, with greater density producing more foliage. Yields for all tree densities increased steadily with time. Rate of foliage production increase per tree, however, was greatest at the lowest tree densities. These rates showed a decline in 1970 for all densities at Boatman, which could have been due to seasonal conditions or to declining production with age. A relationship between leaf yield and tree basal area was shown. (Figure 3).

Tree litter yields were also related to tree density, the highest yields being produced by the densest stands. Though foliage increased with time, litter yields were more variable. This was probably due to the influence of rainfall on litter shedding by mulga trees.

Figure 3. The relationship between tree density or stem basal area and herbage yield in Mulga[1] and Poplar box[2] woodlands



Data from [1] Beale, I.F. (1973)
[2] Walker, J., Moore, R.M. and Robertson, J.A. (1972)

Tree seedling numbers showed the greatest increase on the 160 tree ha^{-1} plots at Monamby. Seedling-herbage competition in the 40 tree ha^{-1} treatments was greater due to less suppression of herbage by the trees while seedling-tree competition was greater in the 640 tree plots. This resulted in fewer seedlings in these extreme treatments. The general lack of seedlings at Boatman was probably related to the lack of mature seed trees in the initial population, which resulted in low residual seed reserves.

Nitrogen and phosphorus contents of tree foliage were lower in the high tree density treatments at both sites, though only significantly so on a few occasions. Conversely, yields of these elements increased with greater tree density. The effect of age in reducing nitrogen and phosphorus contents was shown. Tree litter showed no definite relationship between tree density and content of these elements.

Herbage had higher nitrogen and phosphorus levels under the highest tree densities. A number of explanations for this were advanced. In juxtaposition to contents, yields of these elements were greatest on the lowest tree density plots.

Both tree foliage and herbage yields were linearly related to their yields of nitrogen and phosphorus. This suggested that these elements were not limiting growth on these low fertility sites.

An estimate of net productivity (above ground excluding wood) at the two sites was 0.23 gm m^{-2}/day. This showed that these semi-arid sites were low producers. This value was used to reinforce stocking rate suggestions for these areas.

Crude protein levels for both tree components and herbage was above 5% for all harvests, with tree foliage and litter usually the higher. Phosphorus levels for both were low by dietary standards. It suggested that animal diets would be adequate in both if sufficient forage was present to allow selective grazing. This will have to be confirmed by animal experimentation.

Management strategies for the region suggest heavily thinned areas for herbage production and scrub areas for drought fodder reserves. An optimization study will be needed to determine the size of each area.

Pasture basal area measurements commenced in 1975. Those at "Boatman" decreased from 8.3% in the 40 trees ha^{-1} to 6.9% and 4.4% in the 160 and 640 trees ha^{-1} treatments respectively. At "Monamby" the equivalent basal areas were 2.0%, 1.2% and 1.3%. Botanical composition was similar under the three treatments at both sites, though, at "Boatman", Digitaria ammophila decreased with increasing mulga tree density, and Monachather paradoxa and Enneapogon spp. increased with increasing density. Aristida spp. were dominant grasses under all treatments at both sites.

At "Boatman" 14 of the 21 plots were burnt in October 1975. Basal cover and botanical composition were recorded before burning and again in August 1976 and September 1981. Basal area in all plots was lower in 1976 than in 1975 (40 trees ha^{-1}, 8.3 to 5.9%). In 1981, there were virtually no live tussocks but a large mass of winter herbage and a number of grass seedlings were present. Basal area in 1981 was <1% in all plots. The extended summer drought from 1977 to October 1981 contributed to the decline in perennial grass cover.

At "Monamby", band transects were used to record changes in mulga and woody weed numbers. Transects were used in 1964 to determine the density of mulga before the thinning treatments were imposed, and again in October 1975 and 1981 to record mulga and other woody species. The density of mulga trees has stabilized inside and outside of plots at "Monamby" following a flush of regeneration that followed the initial clearing (Table 2).

TABLE2. Density of mulga (trees ha^{-1}) at "Monamby".

	Outside	40 trees ha^{-1}	160 trees ha^{-1}	640 trees ha^{-1}
1964	3 000	40	160	640
1975	1 400	2 100	1 700	790
1981	1 500	1 900	1 900	1 400

The density of woody weeds fluctuated (Table 3). Mature *Eremophila gilesii* reached a density of 22 000 shrubs ha^{-1} but, by 1981 was almost absent. Although there was a massive germination in that winter. Attacks by the wingless grasshopper (*Monistria discrepans*) were probably responsible for this decline. *Eremophila bowmanii*, on the other hand, has maintained the same numbers of between 2 000 and 4 000 shrubs ha^{-1} since 1975. A similar pattern of change occurred in the small exclosures on other mulga land systems where these species occur (CLE-P2-WR).

Regeneration of mulga and invasion by woody weeds were major factors affecting the ground flora at "Monamby". Mulga regeneration was 2 100, 1 700 and 790 trees ha^{-1} in the 40, 160 and 640 trees ha^{-1} treatments respectively (Table 2). The *Eremophila bowmanii* densities for the 160 trees ha^{-1} treatments were 3 735, 1 950 and 2 711 shrubs ha^{-1} (Table). No *E. gilesii* shrubs were encountered in a survey of the area before thinning in 1964. Other woody weeds such as *Prostanthera* spp., *Cassia nemophila* and *Eremophila longifolia* have increased in density from 1964 to 1975 and then declined.

TABLE 3. Populations of woody weeds at "Monamby" 1964-1981 under a mature tree density of 160 ha^{-1}

Species	1964	1975	1981
Eremophila bowmanii	150 ± 100	1 950 ± 285	2 036 ± 325
E. gilesii	0	14 625	9 ± 5
E. longifolia	0	125	51 ± 29
Cassia nemophila	0	125	15 ± 6
Prostanthera suborbicularis	0	1 750	74 ± 51

The reason for these increases could have been a result of the above average rainfall in 1973 and 1974 rather than a stocking factor; a survey outside the exclosure also revealed increases in density of mulga and *Eremophila* spp.

Publications: BEALE, I.F. (1970, 1971, 1973), BEALE, I.F. and BURROWS, W.H. (1968), BURROWS, W.H. (1973a, 1976), BURROWS, W.H. and BEALE, I.F. (1969, 1970), JOHNSON, R.W. and BURROWS, W.H. (1981) .

Succession and seasonal defoliation of some native pasture communities exclosures. (CLE-P2-WR)

(compiled by Dr. R.G. Silcock)

The aim of this trial was to monitor long term vegetation changes on selected land systems of south west Queensland which may have resulted from grazing with domestic livestock.

Treatments were:-

(a) Total exclosure of sheep and cattle and most kangaroos.
(b) Normal paddock grazing by domestic and wild animals.

Seventeen exclosures were erected on a range of landsystems about which landholders had expressed concern.

1. Woody shrub invasions sites - Turn Turn (5)*, Maxvale (6), Lanherne (7), Middleton (8)
2. *Aristida* invasion sites - Airlie (9), Stirling Downs (10)
3. Mulga loss sites - Lesdale (1), Boatman (2), Monamby (3), Wittenburra (4)
4. Cassia invasion sites - Koonawalla (17), Bayswater (14), (potentially)
5. Claypan formation sites - Nulla (11), Boothulla (12), Willacoora (13), Wongalea (15)
6. Spinifex degradation sites - Wongalea Farm (16)

* Location (Site No)

Site information is given in Tables 4 and 5. Results from this trial include:

EFFECT OF SEASONAL CONDITIONS

Recording began in some very dry years e.g., 1965, early counts were often low and species hard to identify. Wet summers occurred in 1973, 1974, 1975 and 1976, but recording was only done in 1973 during this period. Then followed a period to 1986 when the summers were often very dry, e.g., 1980/81 but the winters exceptionally wet. There has been a full range of seasonal conditions experienced during this observation period.

Table 6 shows the nominal mean annual rainfall for each site (range 300-500mm), but no figures have been collected. It was not uncommon for some sites to be extremely droughted while others at the same time were enjoying a good season, e.g., in June 1982, the Tambo/Augathella area (Sites 8, 10, and 14) was having a good season while the Cunnamulla area was severely drought affected (Sites 9, 11 and 13). Hence, comparisons at any time between sites with similar vegetation are influenced by local climatic conditions.

Overall, antecedent rainfall had a much more obvious effect on botanical composition than exclusion of stock. Both stock and rainfall created obvious differences in standing dry matter and each could produce dramatic differences across the fenceline.

Table 4

Location, fencing and sampling dates, and reasons for setting up each of the 17 exclosures (Cle-P2-WR)

No.	Exclosure Name	National 1:250 000 Map Reference	Date Fenced	Reason for picking this site	Dates Vegetation Recorded	Dates Photographed
1	Lesdale	SG55-10(72.3/45.4)	16.2.65	Mulga regeneration?	1966, 26.3.73, 8.6.82	3.73, 6.82
2	Boatman	SG55-14(61.9/50.6)	7.7.64	Mulga regeneration	27.8.64, 21.4.66, 15.8.67, 3.7.70, 27.3.73, 28.6.82	3.73, 6.82
3	Monamby	SG55-9(69.2/33.3)	30.8.64	Mulga/turkey bush regeneration	12.10.64, 30.3.66, 21.7.70, 11.4.73, 16.6.82	4.73, 6.82
4	Wittenburra	SH55-1(46.8/26)	3.3.66	Mulga regeneration	19.5.66, 29.8.67, 23.7.73, 23.6.82	7.73, 3.74 4.80, 6.82
5	Turn Turn	SH55-1(46.7/27.2)	15.2.66	Woody weed increase	19.5.66, 24.8.67 9.7.70, 23.7.73 23.6.82	8.73, 4.80, 6.82
6	Maxvale	SG55-10(73.6/40.5)	15.2.65	Dense green turkey bush	15.3.66, 25.5.67, 26.8.70, 18.3.73, 8.6.82	3.73, 6.82
7	Lanherne	SG55-9(68.3/30)	31.8.64	Dense green turkey bush	16.10.64, 23.6.66, 17.8.67, 18.11.70, 15.5.73, 16.6.82	5.73, 6.82
8	Middleton	SG55-6(78.5/39.9)	7.3.64	Dense grey turkey bush	6.7.64, 1966? 12.7.73, 9.6.82	7.73, 6.82
9	Airlie	SG55-14(60.6/40.1)	27.1.65	Feathertop infestation	5.66, 16.8.67, 27.8.73, 6.3.84	3.73, 6.82 3.84
10	Stirling	SG55-6(87.9/41)	18.2.65	White spear, feathertop infestation	5.5.66, 19.6.68 13.7.73, 18.1.80, 22.6.82	7.73, 6.82
11	Nulla	SG55-14(53.6/36.3)	16.2.66	Claypan regeneration	19.5.66, 31.8.67, 28.3.73, 6.3.84	3.73, 6.82 3.84
12	Boothulla	SG55-9(72.3/31.8)	11.3.66	Mitchell grass regeneration on claypans	3.6.66, 18.8.67 16.5.73, 11.6.82	5.73, 6.82

Table 4 con't

No.	Exclosure Name	National 1:250 000 Map Reference	Date Fenced	Reason for picking this site	Dates Vegetation Recorded	Dates Photographed
13	**Willacoora**	SH55-2(48.1/38.3)	17.2.66	Mitchell grass regeneration on scalded area	19.5.66, 29.8.67 29.3.73, 24.6.82	3.73, 6.82
14	**Bayswater**	SG55-6(83.4/35.4)	10.3.66	Waterspreader	31.5.66, 21.8.67, 26.6.68, 2.9.74	7.73, 6.82
15	**Wongalee**	SG55-14(60.8/46.9)	5.3.65	Yarran swamp vegetation	20.4.66, 16.8.67, 3.7.70, 18.6.82	3.73, 6.82
16	**Wongalee Farm**	SG55-14(62.4/46.8)	26.1.65	Heath and spinifex dynamics	20.4.66, 1967, 3.7.70, 13.9.73, 18.6.82	6.74, 6.82
17	**Koonawalla**	SG55-9(75.3/18.8)	11.3.65	Mitchell grass regeneration and shrubs on mulga soil	21.6.66, 22.8.67, 22.5.73, 21.6.82	5.73, 6.82

PLANT NUMBERS

Up to 7 870 plants were recorded at any one sampling. In very dry times, only a few plants could be found at some sites (Table 6). The number of quadrats without any plants in them varied correspondingly. Rarely were all quadrats at a site occupied by vegetation(Table 6).

Most sites did not show enormous changes in plant numbers over time (range <10 fold for 12 sites) and only sites 11 and 4 showed a range greater than 35 times. This was largely due to extremely low figures in 1966 after the 1965 drought (Table 8). Sites 3, 15 and 16 generally had low numbers of plants but for very different reasons. Site 3 is under a dense mulga canopy and Site 16 has huge spinifex tussocks in it. Site 15 is a swamp/claypan where most herbaceous plants are regularly killed by flooding with salty water.

PLANT DENSITY

Differences in plant density inside and outside the exclosure were rarely large. (Compare Table 10 and 11). Seasonal conditions, not unnaturally, had a much bigger effect e.g., site 4, 17 and 13. However, site 1 had limited changes between recordings, probably due to the times when this site was recorded. The lack of variation at sites 2, 8 and 15 is due to the dominance of trees, shrubs or hummock grasses at these sites which exclude big changes in annual plants, even in good seasons.

Hence, there can be many different, logical reasons put forward to explain site differences in plant density.

SPECIES DIVERSITY

Some sites were always floristically rich (Sites 1, 17 - Table 6) while others were poor (Sites 2, 15 and 16) but most varied considerably depending on antecedent rainfall. Only 210 species were clearly identified out of the 271 categories delimited (Table 7). However, 97 of these (about half) occurred at only one site and only about one quarter were found at two or more sites. Hence, the fact that only about one-third of the species recorded from the region were recorded in the 17 exclosures indicates that either many other vegetation types exist, or that seasonal conditions affected the comprehensiveness of the samples at the dates chosen. In reality, a range of factors contributed, including the smallness of the exclosures, which limited the number of shrub and tree species included. Table 14 shows that woody plants existed in significant numbers only at four sites (6, 7 3 and 16) and were virtually absent from the five heavy soil sites (9, 10, 11, 12 and 13).
The common species and genera, found at over five sites are as follows:-

TREES	Acacia aneura
SHRUBS	Nil
FERNS AND SEDGES	Cheilanthes sieberi, Fimbristylis spp.
FORBS (18)	Alternanthera nodiflora, Abutilon spp. Boerhavia diffusa, Convolvulus erubescens, Evolvulus alsinoides, Erodium crinitum, Euphorbia drummondii, Goodenia spp. Malvastrum americanum, Maireana spp. Phyllanthus spp. Portulaca oleracea, Plantago varians, Pentatropis atropurpureus, Ptilotus spp. Sclerolaena spp., Sida spp. and Velleia spp.

Table 5

Exclosure Name	Land Type WARLUS[1] Category	Land Type Local description	Soil Type	Soil Characteristics (mean of 6 holes) pH (1:5H_2O) 0-15 cm	pH (1:5H_2O) 30-45 cm	BSES avail P(ppm) 0-15 cm	BSES avail P(ppm) 30-45 cm	Total 0-15 c
Lesdale	M1(M07 WARLUS III)	Arabella mulga	shallow greyish red earth on a slope	5.3	5.3	9	7	0.05
Boatman	H3(H02 WARLUS III)	Nebine mulga	mulga red sandy clay loam	5.1	5.1	6	5	0.05
Monamby	M4(Unit 49 WARLUS I)	Cooladdi mulga	shallow red earth	5.1	4.7	14	12	0.08
Wittenburra	H2(Unit 52 WARLUS I)	Eulo mulga	shallow red earth	4.8	5.0	5	2	0.06
Turn Turn	S2(Unit 61 WARLUS I)	Eulo sandplain	sandy red earth	5.7	6.2	11	3	0.04
Maxvale	M3(M15 WARLUS III)	Mulga/box flat	loamy red earth	5.4	5.2	13	5	0.05
Lanherne	M3(Unit 81 WARLUS I)	Mulga/box flat	silty red clay loam	5.1	5.3	12	5	0.06
Middleton	M1(Unit 52 WARLUS IV)	Tableland mulga	shallow red earth	4.5	4.5	5	<5	0.06
Airlie	A2(A16 WARLUS III)	Treeless mitchell grass	cracking grey clay (no scalding)	8.5	8.9	13	10	0.05
Stirling	P1(Unit 1 WARLUS IV)	Tambo open mitchell grass downs	cracking grey clay (no scalding)	8.0	8.5	79	74	0.07
Nulla	G2(A03 WARLUS III)	Brown claypan	scalded brown clay claypen	7.4	8.1	20	26	0.14
Boothulla	A3(Unit 31 WARLUS I)	Scalded river frontage	scalded grey clay claypan	5.5	6.6	16	15	0.06
Willacoora	G2(A29 WARLUS III)	Scalded mitchell grass	scalded brown sandy clay	7.4	7.7	15	16	0.04
Bayswater	W3(Unit 71 WARLUS II)	Alluvial flat	massive brown clay	5.9	7.6	7	<5	0.07
Wongalee	L1(L02 WARLUS III)	Seasonal yarran swamp	massive, saline grey loam (swamp)	7.5	6.8	7	6	N.A.
Wongalee Farm	N1(T01 WARLUS III)	Spinifex heathland	sandy yellowish earth	4.7	4.6	<5	<5	0.02
Koonawalla	W6(Units 34/51 WARLUS I)	Junction of mulga and mitchell grass country	red earth/cracking grey clay transition zone	6.6	7.8	7	6	0.05

[1] WARLUS Western Arid Region Land Utilisation Survey. Division of Land Utilisation. Qd Dept. Prim. Ind.

Soil and Vegetation data for each of the 17 exclosures (Cle-P2-WR)

Table 6

Cle-P2-WR Summary

Plot	Times Recorded	Plants Counted Max.	Plants Counted Min.	Plant Categories Max.	Plant Categories Min.	Bare Sub-Quads Max.	Bare Sub-Quads Min.	MAR (mm) in area
1	3	1 598	1 103	49	24	83	28	500
2	6	1 525	351	18	5	86	47	450
3	5	793	201	23	16	168	109	400
4	4	3 554	3	34	2	266	8	300
5	5	2 601	119	27	6	190	54	300
6	5	2 216	406	41	16	146	33	375
7	6	3 541	37·4	37	10	113	1	350
8	4	1 170	549	27	15	65	24	475
9	4	5 136	281	35	13	90	0	400
10	5	2 597	456	35	19	46	0	450
11	4	2 563	1	23	1	259	5	325
12	4	2 905	591	28	14	137	19	350
13	4	5 800	261	24	12	150	4	325
14	4	2 607	405	38	17	98	1	500
15	4	326	119	7	5	227	170	450
16	5	338	75	11	8	207	112	450
17	4	7 871	930	45	30	43	0	300
Range	MA 6	7 871	1 103	49	30	266	170	
	MI 3	326	1	7	1	43	0	

Table 7

Cle-P2-WR Summary

Indications of the species and genera frequently encountered in the pastures.

Note: All capital letters means a family name while genera have only the first 2 letters in capitals and species have only the first letter a capital. e.g., CYPE = Cyperaceae, CYpe = *Cyperus* spp. and Cybi = *Cyperus bifax*

First letter of category name	Total No. of categories beginning with this letter	No. occurring at only 1 site	No. at 2 sites	No. at 3-5 sites	No. and names at 6-10 sites	No. and names where found at >10 sites
A	27	11	2	8	4 Acan, Alno, Arco, Arje	2 ARis, ABut
B	13	4	3	5	1 Bodi	
C	37	22	7	3	5 Chsi, COMP, Coer, CYPE, CHlo	
D	14	6	1	2	4 DICO, Dibr, Diam, Dise	1 Dara
E	37	14	7	9	5 Eval, ENne, Enpo, Erlac, Ercri	2 Eudr, ERag
F	3	1	1	0	1 FImb	
G	10	6	2	0	2 GOod, GRAM	
H	12	7	3	2		
I	2	1	0	1		
J	0					
K	0					
L	6	5	0	0	1 LILI	
M	15	8	3	1	3 Maam, Mopa, MAir	
N	3	0	3			
O	1	0	0	1		
P	31	10	6	7	8 Pade, PHyl, POrt, Pool, Plva, Peat, Paef, PTil	
Q	0					
R	2	1	1			
S	35	10	10	11	3 Spca, SCle, Spac	1 SIda
T	13	4	3	3	1 Thmi	2 Trlo, Trau
U	1	0	1			
V	7	4	1	1	1 VEll	
W	2	0	1	1		
X	0					
Y	0					
Z	0					
TOTAL	271	114	55	55	39	8

GRASSES (19) Aristida contorta, Aristida jerichoensis, Aristida spp. Chloris spp., Digitaria brownii, Digitaria ammophila, Dichanthium sericeum, Dactyloctenium radulans, Enneapogon spp., Eragrostis lacunaria, Eragrostis spp., Monachather paradoxa, Panicum decomposition, Panicum effusum, Sporobolus caroli, Sporobolus actinocladus, Thyridolepis mitchelliana, Tripogon loliiformis and Tragus australianus.

Of the 18 forbs, very few are really perennial (only Pentatropis and Sida) while in the grasses, five are strongly perennial and only three are true annuals. So the grasses are the widespread dominant herbaceous perennials - not unexpectedly.

Table 7 also emphasises that each soil type has a different suite of adapted perennial plants. Only in good seasons will common annual or short- lived perennials such as those listed above, be found on a wide range of soil types.

INSIDE VERSUS OUTSIDE EXCLOSURES

When the data in Tables 10 and 11 are examined, it is seen that at only a few sites was plant density inside the exclosure more than double that outside where regular grazing occurred. By the 1980's after nearly 20 years exclosure, the range was 0.5 to 13 times. At 4 sites, the plant density outside was greater than that inside, so exclusion of domestic animals does not automatically lead to a greater long-term plant density. A similar story emerged when the perennial grass data was analysed.

Exclosure seems to favour the woody plants (Table 14), particularly the Eremophila and Acacia species. So removal of animals is not the answer to problems caused by those species. There are indications that numbers of woody plants may be decreasing inside the fence at sites 17 and 6, but this may be just temporary or due to spatial rearrangement of the shrubs.

OTHER OBSERVATIONS

A fire burnt through the Maxvale plot (site 6) in the late 1970's but we have no idea of when, as it was very localised and may have been deliberately lit. A deliberate attempt was made in late 1979 to burn the shrubs in the paddock where Site 5 is located. It appeared that it was only a cool burn at the site and little damage was done to the shrubs. However, the Eragrostis eriopoda was severely burnt and in the ensuing drought, its crowns were very badly exposed and pedestalled by wind erosion of the surface sand.

The Middleton (site 8) fire was very hot and burnt all Eremophila bowmanii plants back to the ground and killed most small mulgas. However, a big storm on the evening of the fire ensured most E. bowmanii bushes resprouted quickly. The net effect was a singeing of eucalypts, death of most mulgas and no effect on the E. bowmanii problem, which was supposed to have arisen only after a fire in the 1950's.

CONCULSIONS

1. Generally, the exclosures gave no useful analysable information about woody plants because they were too small. Exceptions were the turkey bushes (Eremophila gilesii and E. bowmanii) and possibly mulga.

Table 8.

Cle-P2-WR Exclosures   Total Plant Numbers

Name	Site No.	Year 1964	1966	1967	1968	1970	1973	1974	1980	1982	1984	Range (Times)	Min.
S/DNS	10		1 160		985		2 597		456	715		5.7	456
AIRL	9		281	969			5 136				1 982	18.3	281
WILC	13		3 222	4 080			5 800			261		22.2	261
NULLA	11		1	936			1 676				(2 563)	2 563.0	1
BOOTH	12		696	591			2 905			(1 820)		4.9	591
BAYS	14		405	(542)	1 749			2 607				6.4	405
KOON	17		1 157	1 746			7 871			930		8.5	930
LANH	7	(675)	1 362	1 048		371	3 541			2 246		9.5	371
MAXV	6		627	1 919		406	2 216			993		5.5	406
LESD	1		1 103				1 508			1 598		1.4	1 103
MIDDL.	8	549	1 042				1 170			1 121		2.1	549
MON	3	201	667			346	793			234		3.9	201
T/T	5		119	3 999		306	2 601			314		33.6	119
WITT.	4		3	234			3 554			315		1 184.7	3
BOAT	2	351	470	368		470	1 525			419		4.3	351
WON	15		119	188		121				326		2.7	119
WON(F)	16		182	269		169	338			75		4.5	75

( ) = incomplete counts

Table 9.

Cle-P2-WR Exclosures Plant Species Diversity

Name	Site No.	1964	1966	1967	1968	1970	1973	1974	1980	1982	1984	Max.
S/DNS	10		32		23		35		19	26		35
AIRL	9		14	13			26				35	35
WILC.	13		12	24			16			20		24
NULLA	11		1	23			7				21	23
BOOTH	12		14	19			28			25		28
BAYS	14		17	25	28			38				38
KOON	17		31	30			43			45		45
LANH.	7	10	17	20		10	37			27		37
MAXV.	6		23	26		16	33			41		41
LESD.	1		24				36			49		49
MIDDL.	8	15	15				19			27		27
MON	3	16	23			21	21			20		23
T/T	5		6	19		11	27			9		27
WITT.	4		2	26			34			33		34
BOAT	2	5	16	17		10	18			16		18
WON	15		5	7		6				6		7
WON(F)	16	8	9			10	11			10		11

Table 10.

Cle-P2-WR Exclosures Plant Density m^{-2} (Inside exclosure)

Site Name	Site No.	Recording Sequence 1	2	3	4	5	6	Range
STIRLING DNS	10	26.3	19.0	63.6	8.9	12.8		9-64
AIRLIE	9	6.8	29.5	130.0	52.3			7-130
WILLACOORA	13	65.1	93.2	149.3	6.9			7-149
NULLA	11	0.03	18.9	37.4	74.9			0-75
BOOTHULLA	12	16.0	19.6	86.6	54.3			16-87
BAYSWATER	14	12.8	27.9	38.1	71.8			13-72
KOONAWALLA	17	35.0	44.2	237.2	27.9			28-237
LANHERNE	7	94.8	30.6	29.0	11.1	91.4	64.1	11-95
MAXVALE	6	20.5	60.3	13.3	60.3	23.3		13-60
LESDALE	1	14.7	31.6	33.4				15-33
MIDDLETON	8	12.9	28.8	30.7	28.9			13-31
MONAMBY	3	3.2	9.9	8.5	13.6	4.4		3-14
TURN TURN	5	2.6	9.1	6.7	51.0	8.1		3-51
WITTENBURRA	4	0.06	6.1	74.3	5.1			0-74
BOATMAN	2	8.6	14.5	11.0	13.9	48.3	11.3	9-48
WONGALEE	15	3.6	5.1	3.8	10.7			4-11
W/FARM	16	4.1	5.9	4.1	7.2	2.3		2-7

Table 11.

Cle-P2-WR Exclosures — Plant Density m^{-2} (Outside exclosure)

Site Name	Site No.	Recording Sequence 1	2	3	4	5	6	Range
STIRLING DNS	10	27.6	30.2	49.6	13.5	23.1		13-50
AIRLIE	9	6.1	7.6	98.5	30.5			6-98
WILLACOORA	13	93.0	100.2	111.4	3.8			4-111
NULLA	11	0.0	27.8	39.3	25.0			0-39
BOOTHULLA	12	16.1	1.4	24.3	15.0			1-24
BAYSWATER	14	2.2	-	44.9	40.5			2-45
KOONAWALLA	17	9.7	32.1	296.5	7.3			7-296
LANHERNE	7	-	32.9	14.3	3.2	64.6	25.5	3-65
MAXVALE	6	3.9	7.4	0.3	35.0	20.5		0-20
LESDALE	1	49.6	41.5	43.9				41-50
MIDDLETON	8	11.7	15.9	17.5	26.5			12-26
MONAMBY	3	7.7	26.2	6.5	27.2	7.2		6-27
TURN TURN	5	3.0	9.4	7.3	72.6	5.0		3-73
WITTENBURRA	4	0.0	4.1	96.6	11.4			0-97
BOATMAN	2	7.4	4.1	3.2	4.6	7.1	6.0	4-7
WONGALEE	15	1.0	2.6	0.6	0.8			1-3
W/FARM	16	4.3	6.5	3.4	8.7	0.5		1-9

Table 12.

Cle-P2-WR Exclosures

Total plant numbers, Inside (outside) the fence at each recording time.
Note: The area recorded inside the fence (44 quadrats) was about twice that done outside (22).

Name	Site No.	Recording Sequence 1	2	3	4	5	6	Total
STIR	10	767 (393)	555 (430)	1 875 (722)	259 (197)	378 (337)		5 913
AIRL	9	194 (87)	860 (109)	3 829 (1 307)	1 532 (450)			8 368
WILL	13	1 897 (1 325)	2 717 (1 363)	4 375 (1 425)	203 (58)			13 363
NULL	11	1 (0)	540 (396)	1 103 (573)	2 207 (356)			5 176
BOOT	12	467 (229)	571 (20)	2 551 (354)	1 601 (219)			
BAYS	14	373 (32)	542 (-)	1 109 (640)	1 860 (747)			
KOON	17	1 019 (138)	1 289 (457)	6 911 (960)	823 (107)			
LANH	7	675 (-)	893 (469)	844 (204)	326 (45)	2 662 (879)	1 879 (367)	
MAXV	6	571 (56)	1 816 (103)	402 (4)	1 717 (499)	687 (306)		bare area outside
LESD	1	428 (675)	930 (578)	972 (626)	termite mound inside.			
MIDD	8	379 (170)	836 (206)	904 (266)	843 (378)			3 982
MONA	3	91 (110)	294 (373)	253 (93)	388 (405)	130 (104)		
TURN	5	76 (43)	265 (134)	200 (106)	1 520 (1 081)	241 (73)		
WITT	4	3 (0)	178 (56)	2 116 (1 438)	145 (170)			
BOAT	2	246 (105)	412 (58)	321 (47)	405 (65)	1 422 (103)	329 (90)	
WONG	15	104 (15)	149 (39)	112 (9)	315 (11)			
W/FRM	16	121 (61)	177 (92)	121 (48)	214 (124)	68 (7)		1 033

Table 13.
Cle-P2-WR Exclosures

Perennial grass numbers, Inside (Outside) the fence at each recording time.
Note: The area recorded inside the fence (44 quadrats) was about twice that done outside (22).

Name	Site No.	Recording Sequence 1	2	3	4	5	6	Total	Percentage of all plants
STIR	10	546 (344)	411 (155)	1 242 (196)	190 (179)	156 (166)		3 585	61
AIRL	9	71 (47)	475 (65)	778 (322)	876 (112)			2 746	33
WILL	13	491 (182)	752 (752)	1 824 (1 055)	68 (43)			5 167	39
NULL	11	0 (0)	9 (65)	0 (15)	163 (86)			338	6
BOOT	12	338 (177)	190 (4)	113 (10)	7 (2)				14
BAYS	14	95 (13)	167 (-)	281 (348)	773 (264)				37
KOON	17	379 (1)	262 (37)	1 130 (7)	132 (10)				17
LANH	7	199 (-)	513 (395)	524 (105)	111 (1)	1 537 (51)	1 268 (103)		52
MAXV	6	246 (22)	792 (17)	349 (0)	940 (103)	228 (28)			44
LESD	1	152 (133)	184 (106)	637 (283)					35
MIDD	8	197 (82)	587 (125)	655 (113)	497 (234)			2 490	62
MONA	3	10 (33)	181 (247)	104 (40)	192 (130)	53 (45)			46
TURN	5	69 (41)	158 (80)	105 (61)	1 196 (979)	182 (46)			76
WITT	4	0 (0)	35 (10)	215 (30)	80 (116)				12
BOAT	2	105 (74)	104 (24)	122 (4)	257 (35)	1 112 (70)	75 (29)		56
WONG	15	0 (0)	0 (0)	0 (0)	0 (0)			0	0
W/FRM	16	86 (51)	137 (68)	96 (43)	96 (42)	39 (2)		660	64

Table 14.

<u>Cle-P2-WR Exclosures</u>

<u>Woody Plants</u>, Inside (Outside) the fence at each recording time.

Note: The area recorded inside the fence (44 quadrats) was about twice that done outside (22).

Name	Site No.	Recording Sequence 1	2	3	4	5	6
STIR	10	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
AIRL	9	0 (0)	0 (0)	0 (0)	2 (0)		
WILL	13	0 (0)	0 (0)	0 (0)	0 (0)		
NULL	11	0 (0)	0 (0)	0 (0)	0 (0)		
BOOT	12	0 (0)	0 (0)	0 (0)	1 (0)		
BAYS	14	6 (0)	19 (-)	4 (0)	19 (13)		
KOON	17	16 (0)	26 (1)	11 (0)	3 (0)		
LANH	7	89 (-)	128 (43)	142 (35)	159 (39)	73 (13)	478 (224)
MAXV	6	64 (0)	108 (2)	36 (2)	23 (2)	24 (2)	
LESD	1	2 (2)	2 (2)	5 (2)			
MIDD	8	59 (40)	71 (35)	81 (45)	28 (35)		
MONA	3	8 (5)	4 (2)	5 (3)	5 (3)	5 (3)	
TURN	5	3 (0)	8 (4)	3 (2)	7 (4)	13 (15)	
WITT	4	0 (0)	1 (0)	3 (0)	3 (0)		
BOAT	2	9 (7)	12 (2)	4 (3)	6 (7)	3 (6)	5 (5)
WONG	15	2 (0)	2 (0)	1 (0)	2 (0)		
W/FRM	16	22 (3)	21 (4)	21 (5)	59 (9)	25 (4)	

Table 15.

Cle-P2-WR Exclosures

Bare Cells, Inside (Outside) the fence at each recording time. Each quadrat had 4 equal cells.
Note: The area recorded inside the fence (44 quadrats) was about twice that done outside (22).

Name	Site No.	Recording Sequence 1	2	3	4	5	6
STIR	10	2 (3)	1 (0)	0 (0)	43 (3)	25 (1)	
AIRL	9	57 (33)	8 (24)	0 (0)	0 (0)		
WILL	13	35 (0)	3 (1)	4 (9)	90 (60)		
NULL	11	179 (80)	29 (12)	5 (34)	0 (5)		
BOOT	12	39 (20)	57 (80)	16 (55)	1 (18)		
BAYS	14	31 (67)	4 (-)	1 (0)	0 (1)		
KOON	17	14 (29)	12 (4)	0 (0)	4 (33)		
LANH	7	1 (-)	15 (16)	11 (30)	54 (59)	0 (2)	3 (21)
MAXV	6	48 (67)	21 (50)	59 (87)	23 (23)	22 (11)	
LESD	1	80 (3)	60 (3)	23 (5)			
MIDD	8	41 (24)	31 (20)	30 (16)	16 (8)		
MONA	3	112 (22)	108 (18)	117 (51)	89 (20)	99 (26)	
TURN	5	133 (57)	70 (30)	88 (38)	47 (7)	82 (44)	
WITT	4	174 (92)	124 (56)	7 (1)	93 (32)		
BOAT	2	29 (48)	20 (49)	37 (49)	29 (51)	21 (48)	4 (43)
WONG	15	130 (85)	102 (68)	111 (80)	142 (85)		
W/FRM	16	99 (50)	80 (32)	106 (52)	95 (37)	123 (84)	

2. For annual species, the recordings were not been frequent enough to do more than itemise species presence. No good indication is given of their regularity of germination or their potential to contribute fodder.

3. Useful site-specific information is given on major perennial grasses and their population fluctuations.

4. The data are too poorly identified to make general computer analysis meaningful. However, some major species at some sites may be amenable to computer analysis.

5. The data for Cheilanthes, Tripogon, Cyperaceae, Marsilea and some Convolvulaceae and Goodenia spp., are only useable as presence or absence, i.e., frequency, because the numbers are usually too dense to count and individual plants hard to delineate because the plants are rhizomatous.

6. Seasonal conditions have a far greater impact on species composition and plant density of the pastures (as they existed by the mid-1960's) compared to the effects of grazing management. Management has had its greatest effect on biomass of feed available and its feed value (via selective grazing).

7. The data gave useable plant density data but the value of this for extension and research is small.

8. The photographs are probably as useful on this scale as the objective data. Unfortunately, none were taken in 1964-67 when the plots were established.

9. The following species would justify further ecophysiological study, based on their frequency of occurrence at the exclosure sites. (? indicates doubtful value on other agronomic grounds).

Alternanthera nodiflora?	Eriochloa spp.
Digitaria brownii	Erodium crinitum
Sida spp.	Convolvulus erubescens
Panicum effusum	Chloris sp. e.g., C. divaricata
Enneapogon polyphyllus?	Evolvulus alsinoides

10. Exclosure per se did not lead to an improvement in botanical composition, but produced more feed in the short term. Grey and green turkey bush (Eremophila bowmanii and E. gilesii respectively), showed no signs of thinning out when exclosed, even though competition from grass was potentially greater.

11. Mulga (Acacia aneura) regenerated quite well on all sites on red earth soils where stock were removed.

12. White spear (Aristida leptopoda) and feathertop (A. latifolia) did not decline on mitchell grass areas when grazing was curtailed. On Site 10, the mitchell grasses (Astrebla spp.) deteriorated in the absence of regular grazing.

13. Scalds and claypans did not return to productive land just by removing grazing animals. Some form of mechanical alteration of the soil surface is also needed.

Many other specific pieces of information have been gleaned from these exclosures. These are contained in the individual site summaries retained at the Charleville Laboratory. Such information has enabled advice or explanation to be given for many previously unexplained or poorly documented phenomena in the region. The data on specific species or sites can be accessed readily by anybody interested in that particular information.

Toorak Exclosure (RMD-P8-WR).

An exclosure was established in 1963 to determine the effect of the grazing animal on the behaviour of Aristida latifolia within the Astrebla/Iseilema association. No treatments were imposed other than protection. Observations were also recorded on a similar plot, adjacent to the exclosure but grazed by sheep.

Between 1963 and 1969, feathertop density decreased considerably in both the exclosure (from 43% to 15% of the perennial population) and the adjacent grazed area. It is suggested that these changes have been caused by moisture stress rather than presence or absence of grazing or competition from other species. Rainfall was low in 1967 and 1969, severely so in the latter period.

Density of native grasses in mulga communities of south-west Queensland (CLE-P36-WR)

Mulga (Acacia aneura) leaves provide adequate protein, but only maintenance energy for animal nutrition (Everist et al., 1958). The size class distribution and leaf yield relationships of mulga trees in grazing lands of south-west Queensland indicate that there are sufficient trees in most areas to satisfy present and future animal needs if sensible management is practised (Burrows and Beale, 1970). These studies suggest that, in times of stress, energy rather than protein would be the principal dietary deficiency of animals grazing on Queensland's mulga lands. As energy is usually provided by the grass component of pastures, an examination of the grass population density in the mulga lands seems warranted. A further reason for making such a study is the soil holding and water retention role of grasses in limiting soil erosion in this semi-arid region.

Preliminary results of surveys of the grass density in several defined but widely separated mulga communities of south-west Queensland are presented in Table 16.

As would be expected, the grass density varied markedly with tree number. If all sites are combined, there appears to be an inverse curvilinear relationship between grass and tree densities. Despite large differences in soil depth, in preceeding precipitation, and in time of clearing, the grass density under the two lighter mulga stands is very similar.

TABLE 16

Grass density recorded in several mulga communities

Mulga trees per ha	Grass density (tussocks per m^2)		
	Monamby	Boatman	Charleville
40 (actual)	19.0 ± 3.0a	18.0 ± 1.2a	N.O.
160(actual)	15.8 ± 2.3a	13.3 ± 0.9b	N.O.
640 (actual)	11.6 ± 1.8a	4.9 ± 0.7b	N.O.
1922 ± 146	9.6 ± 1.2**	N.O.	N.O.
5503 ± 610	N.O	1.7 ± 0.2b	N.O.
8218 ± 1173	N.O.	N.O.	0.8 ± 0.1c

Recording Date:- a = June 1967; b = August 1967; c = November 1968
N.O. Not obtained

Note: (a) Individual small tufts (not tillers) were counted at all sites.
(b) The extremely short-lived ephemeral *Tripogon loliiformis* was ignored in these counts at all sites.

This suggested that grass densities of the order of 11-22 small tussocks per square metre were somewhere near the maximum obtainable under these conditions. In most seasons, there was considerable bare ground, even in open mulga country protected from stock. In good seasons, some of this bare ground may be occupied by ephemeral forbs.

Grass densities were much lower and also more variable under denser mulga stands. From past observations, it appeared that grass density under dense mulga stands strongly reflects the previous few months rainfall. This was confirmed in the case of the 640 trees ha^{-1} stands where Boatman received 100mm and Monamby 275mm during the four months prior to the grass counts. The increasing competition from trees was apparent in the rapid decline in grass density where mulga scrubs thicken up.

The grasses recorded were *Aristida* spp., *Brachiaria piligera, Digitaria brownii, D. ammophila, Enneapogon pallidus, Eragrostis* spp., *Monachather paradoxa, Panicum decompositum, Paspalidium* spp., *Thyridolepis mitchelliana, Tragus australianus* and *Tripogon loliiformis*. Species were common to all sites. This indicated that in open areas the grass species are the same as those native to semi-arid forests. It is suspected that they are poorly adapted to survive even moderate stocking rates.

Publications: BEALE, I.F. and BURROWS, W.H. (1970).

Vegetation responses in degraded lands - "Tobermory" transect (CLE-P11-WR) and "Humeburn" transect (CLE-P12-WR).

Semi-arid savannas, wherever they occur, have generally been overgrazed and encroached on by bush (Walker *et al.* 1981). Since increasing tree or shrub density has a strong depressant effect on associated grass and forb yield (Jameson 1967, Walker, Moore and Robertson 1972, Beale 1973) the dynamics of trees and shrubs in savanna communities are of considerable interest to the applied ecologist and range manager.

The "Humeburn" and "Tobermory" transects (Burrows and Beale 1969) are permanently positioned in mulga (*Acacia aneura*) dominated communities of south-west Queensland and meet all of Austin's (1981) requirements for the study of vegetation dynamics.

These transects are two long term ecological studies of vegetation dynamics in mulga (*Acacia aneura*) lands. Perennial woody vegetation is monitored over a total of 64 km in a 2m wide, permanently positioned "belt". The Humeburn transect is situated on land adjacent to the Paroo River and the Tobermory transect is in the Grey Range south-west of Quilpie. Both transects were established in the severe drought year of 1965. For both sites, rainfall was average or below from 1965 to 1972 and in 1979, and above average from 1973 to 1978. The number and position of all woody plants (within 0.2 m^2) are recorded. In addition, the dominant tree form (mulga) is categorised in different size classes. Photographs are taken at each marker peg at each recording to provide a pictorial record of changes in vegetation.

The results for each of the study areas were interpreted by means of association analysis. Several site groups were recognized, in which increasing elevation from the flats to the ridges seems to be the main factor consistent with community changes. The density of seedling and young mulga is considered inadequate for future drought reserves at one site. No large species groups exist on either site, and both areas represent small mosaics. It is suggested that microtopography is an important determinant of species distribution in the sites studied.

Data from a 9 km section of the Humeburn transect have been subjected to numerical classification which defines vegetation groups for transition matrix simulation of future changes in tree and shrub density. Records from an additional 5 km of the transect not included in the initial analyses were used to test the reliability of the predictions, after superimposing the original classifications onto this data set. Predicted changes in species populations are in line with documented trends for similar vegetation types in this environment. (Figure 4), i.e. a general increase in woody plant density, especially the woody weeds.

Publications: BURROWS, W.H. (1971, 1973, 1976), BURROWS, W.H. and BEALE, I.F. (1969), BURROWS, W.H., BEALE, I.F., SILCOCK, R.G. and PRESSLAND, A.J. (1984), JOHNSON, R.W. and BURROWS, W.H. (1981), SMITH, F.T., CROWTHER, D.E.F, BOWLY, P.S., EVENSON, C.J., LEHANE, K.J., BEALE, I.F. ROBERTS, B.R. and BURROWS, W.H. (1984).

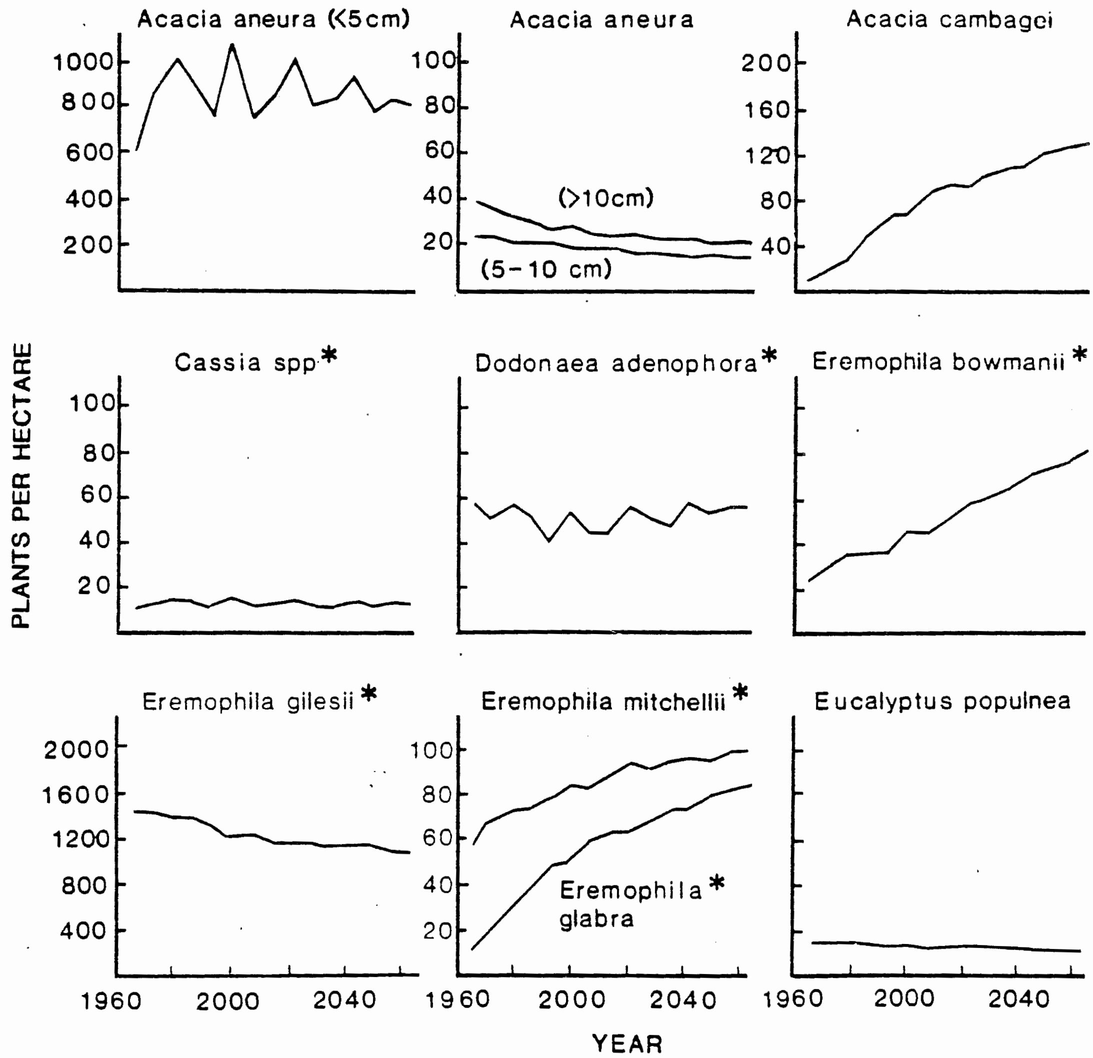


Figure 4. Population projections for woody vegetation on the Humeburn transect. Species with densities <10 ha^{-1} in 1965 are not depicted. Those species marked with an asterisk are regarded as woody weeds. The Acacia aneura size classes are stem diameters measured 30 cm above ground level with seedlings included in the <5 m class. Note the different scales on the Y-axes. (From Burrows, Beale, Silcock and Pressland, 1985),

Phytotoxicity of woody shrubs (CLE-P31-WR)

Small perennial shrubs, chiefly species of *Eremophila*, *Cassia* and *Dodonaea* occupy a considerable proportion of the ground vegetation in south-western Queensland. These species are avoided by stock and their density is such that they often exclude invasion of useful pasture species. One explanation for the exclusive nature of these plants is the possible production of water soluble phytotoxic compounds which inhibit germination of other species.

Preliminary studies have shown that water soluble extracts from the leaves of *Eremophila gilesii* and *E. bowmanii* inhibit the germination of buffel grass and *Thyridolepis mitchelliana* (mulga mitchell). It was also found that a 50/50 soil extract from beneath the canopy of both shrubs significantly delayed and inhibited the germination of buffel grass. A similar extract form inter-shrub areas did not effect germination.

Studies on the ecology of green turkey bush(CLE-P47-WR).

Eremophila gilesii F. Muell., together with other unpalatable or little - used woody shrubs, precludes the growth of grasses and forbs over considerable areas of potentially useful grazing lands in the semi-arid mulga shrublands of south-west Queensland. This study examined some facets of the ecology of *E. gilesii* as a contribution to the understanding of shrub dynamics in the Australian rangeland ecosystem. Ecological aspects which may suggest avenues of control of this major woody weed were examined in detail. Some standard chemical and mechanical control techniques were also evaluated.

E. gilesii is endemic, confined to the Australian Eremean flora, and is closely associated with *Acacia aneura* throughout its distribution but is not found below 30^{o} S latitude. However, it is considered a problem only in south-west Queensland, at the most mesic extremity of its geographical range. Soils on which it occurs are very acid in reaction and low in phosphorus.

In semi-arid Queensland, plant densities of 450 to 69 000 bushes ha^{-1} were recorded. The highest density had an above ground biomass averaging 2100 kg ha^{-1} (over 5 harvests) and a net primary production of 0.23 g m^{-2}/day over 345 days. Both energy conversion and moisture use efficiency are low. Root:shoot ratios decreased from 1.4 to 0.3 with increasing bush age. Above-ground standing crop of nutrients per hectare amounted to 34.8 kg N, 1.9 kg P, 39.6 kg K and 16.8 kg Ca when organic material was 2400 kg in the most dense stand. Litter production varied greatly throughout the period of measurement and, under 69 000 bushes ha^{-1}, approximates an annual rate of 500 kg ha^{-1}. This comprised 0.5% flower buds, 1.8% flowers, 9.3% fruit and 88.4% leaf and stems. By contrast, litter on the soil surface at the final harvest comprised 794 kg ha^{-1} made up of 11.3% leaf, 23.3% stem and 65.3% fruit, with few discernible flower buds and flowers. It is estimated that mean litter decomposition time is approximately 20 months varying form 2-3 months for leaves to about 12 years for fruits. The internal and external cycling of plant nutrients within this shrub community are quite efficient.

Population studies over 5 years have shown that *E. gilesii* is increasing in density under both light grazing pressure and where stock are excluded. The evidence suggests that the plant is favoured (relative to most grasses) by cool season (March-September) rainfalls. Pattern analysis of the vegetation at one site indicated that *E. gilesii* forms monospecific stands in *A. aneura* communities and was not invading areas cleared of, or occupied by, *A. aneura* scrub. *E. gilesii* was negatively associated with other woody plants, apart from mature *A. aneura* trees, and this suggests that after *E. gilesii* is controlled other woody species will not necessarily recolonise such habitats.

The plant commences or continues growth after rains irrespective of season. However, bud formation, flowering, fruit set and germination are favoured by rain in the cool season rather than in the warm season. The flowers are largely self-incompatible. Fruit production is most pronounced after rains occurring between March and September and, in the most dense stand, approximated 1.5×10^6 abscissed fruits ha^{-1} $year^{-1}$. Fruit density on the soil surface is much greater than this. Seeds will germinate only after the woody pericarp of the fruit is weathered and maximum germination of fruits (40-50%) may not occur until about 3 years after abscission. Maximum recorded germination at constant temperature occurs between 15 and 25°C. Germination may be severely inhibited by soil temperature with daytime maxima in excess of 40°C.

Root growth of seedlings is much faster than the growth of shoots. Mean root extension rate under favourable conditions was 2.5 cm day^{-1} with the highest rate of 5.6 cm day^{-1} occurring 14 days after germination. Seedlings can withstand moisture stresses in excess of -100 atmospheres for considerable periods.

Ploughing out stands of *E. gilesii* or slashing at ground level was found to be effective in killing the plant. Many of the common herbicides applied as high-volume foliar sprays will also kill this shrub. A 2,4,5-T-ester/diesel distillate 1% a.i. combination is particularly effective. The plant is periodically attacked by a wingless grasshopper (*Monistria discrepans* Walker). When insect populations are high, large areas of *E. gilesii* are killed.

Grazing managment techniques are also suggested to control *E. gilesii* through heavy stocking following cool season rains in excess of 40 mm.

Publications: BATIANOFF, G.A. and BURROWS, W.H. (1973, 1971, 1972, 1973b, 1974), JOHNSON, R.W. and BURROWS, W.H. (1981), PRESSLAND, A.J. (1981(b).

Rangeland condition and trend surveys (Bk1-P53-WR).

Professor B.R. Roberts, while Head of the Department of Pasture Science at the University of the Orange Free State, Bloemfontein, South Africa, was awarded an Australian Wool Corporation Visiting Research Fellowship to spend one year with the Queensland Department of Primary Industries.

A one year initiating programme was undertaken during 1972 to investigate the possible role of condition and trend studies as a guide to management in semi-arid Queensland. Field work centred on the establishment of "ecological benchmarks" through botanical survey of well preserved samples of vegetation on each major soil type. Survey work was based on the criteria of basal cover and botanical composition as determined by the wheel point method. Thirty-six sites were surveyed, using 800m transects.

The results indicated the potential dominants, sub-dominants and associated species on the four main soil types, namely laterites, sandy red earths, rocky plateaux, and cracking clays.

The study showed that certain basic information was still required before meaningful lists of key species could be drawn up for western Queensland's mulga and Mitchell grass regions. On the basis of the results obtained, lists of species of ground-cover plants were drawn up and tentative key species suggested on the basis of a scoresheet which included the attributes of perenniality, productivity, acceptability, moisture requirements and resistance to grazing. The survey included approximately 65 grasses and 95 non-grasses in the ground cover. Botanically, the laterites supported the most diverse flora, averaging 31 species. Cracking clays had 25 species on average, sandy red earths 20 species and rocky plateau soils only 13 species. Basal cover on protected or well-preserved sites averaged 4.4% on sandy red earths, 3.3% on laterites, 2.8% on cracking clays and 1.1% on rocky plateaux.

On the basis of the survey data, a step-wise procedure for the establishment of condition assessment standards in western Queensland was proposed and investigations aimed at collecting further basic information suggested. A full report on the initial study was compiled and included (i) a description of the soils, climate, vegetation and dynamics of western Queensland, (ii) a literature review of the symptoms and causes of deterioration of semi-arid grazing lands in Australia, (iii) an overview of the significance of condition and trend studies, (iv) details of the Queensland field study, (v) an evaluation of the Queensland results, and (vi) an examination of the needs for and possibilities of vegetation management in semi-arid Australia. It concluded that the low priority which has been accorded <u>integrated long term ecological</u> research in semi-arid Australia was a serious matter which merits large scale action.

Recording of the 36 benchmark sites established in 1972 has continued. On cracking clay soils, a series of summers with above-average rainfall (1972-73 to 1976-77) resulted in a vegetation composition dominated by perennial grasses , while summer drought and above-average winter rainfall (particularly 1978 and 1983) led to a mixed composition of perennial grass and a wide range of summer and winter forbs. The occurrence of annual grasses remained low throughout (Figure 5).

Total basal area increased during the period of above-average summer rainfall and declined during summer drought. <u>Astrebla</u> spp. were the main ones contributing to basal area. Changes in total basal area tended to mirror changes in <u>Astrebla</u> basal area (Figure 6).

<u>Publications:</u> ROBERTS, B.R. (1972, 1975), ROBERTS, B.R., GRAHAM, T.W.G. and ORR, D.M. (1976, 1981, 1986)), ORR, D.M. and HOLMES, W.E. (1984), ORR, D.M. and EVENSON, C.J. (1985) .

<u>Aspects of Nutrient Cycling in Mallee and Mulga Communities</u> (CLE-P64-WR).

A study was made of nutrient distribution and fluxes in mallee and mulga ecosystems to obtain an appreciation of the manner in which the woody plants have adapted to their infertile semi arid habitats. Emphasis was placed on utilisation and fluxes of nitrogen and phosphorus within these ecosystems.

Pool sizes of total phosphorus, "available" phosphorus and total nitrogen within the communities exhibited remarkable similarities despite wide differences in geographical location and plant assemblages supported. There was a pronounced concentration of organic carbon, total nitrogen and "available" phosphorus in the soil surface horizons.

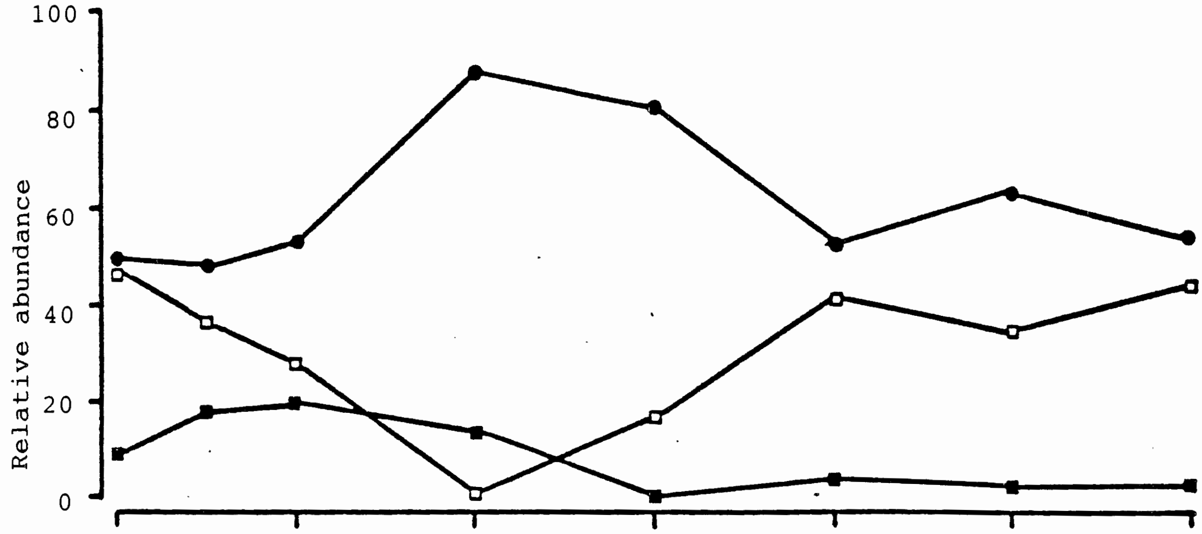


Figure 5. Changes in the relative abundance of perennial grasses (●), annual grasses (■) and forbs (□) in *Astrebla* grassland between 1972 and 1984

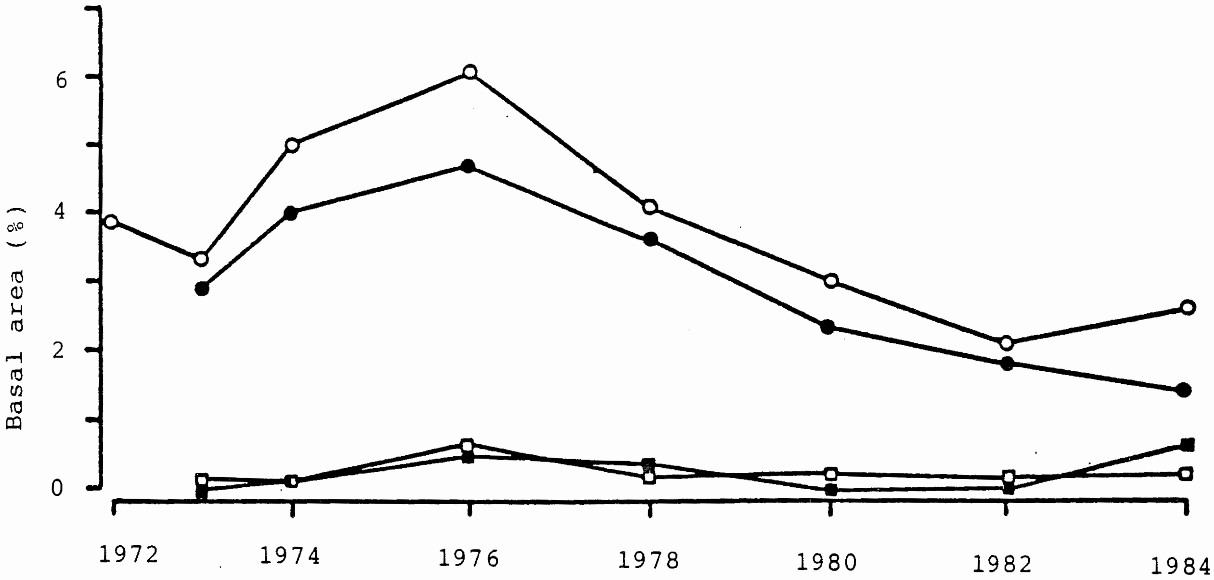


Figure 6. Changes in the basal area of *Astrebla* spp. (●), *Aristida latifolia* (□) and *Dichanthium sericeum* (■) in relation to total basal area (○) in *Astrebla* grassland between 1972 and 1984

High resilience within mallee communities was demonstrated by comparison of a fifteen year regrowth community with an adjacent mature (c. 55 year old) stand. There were only small differences between both communities in nitrogen and phosphorus pool sizes in the vegetation, and in lignotuber biomass, leaf area index and the amount of leaf litter present on the soil surface. The above-ground net primary productivity of the regrowth community (5406 kg ha^{-1} yr^{-1} was more than twice that of the mature mallee (2379 kg ha^{-1} yr^{-1}).

The mulga community had high concentrations of nitrogen in both its living and dead tissues compared with mallee. This suggested that the Acacia/Rhizobium symbiosis was effective but there was apparently no build-up of total nitrogen within the soil profile.

There were considerable fluctuations in the pulses of litter and nutrients onto the floors of these woodland ecosystems. However, litterfall from Eucalyptus spp. exhibited a distinct summer maximum whereas litterfall in mulga appeared to be largely independent of season and rainfall. Withdrawal of nitrogen and phosphorus prior to leaf abscission indicated conservation in the use of these elements.

There were striking similarities in the breakdown and decomposition rates of mallee and mulga leaves, despite higher extant nitrogen concentrations in the latter. Similarly, within a particular community, there was little variation in the decomposition rates on different microsites. The patterns of mineralisation and immobilization of nitrogen and phosphorus in decaying leaves, branches and bark were in broad agreement with similar studies carried out elsewhere in a range of vegetation types.

It was demonstrated that the widely accepted decay constant is an unstable value which changes as decomposition progresses. Derivation of this value by the assumption of "steady-state" in mature semi-arid shrub and woodland communities appears to be equally tenuous.

There was no suggestion of a specific xerophytic microflora being present on decomposing mallee and mulga leaves. The pattern of species colonization was consistent with that found elsewhere in Australia. A feature of the microflora was that only three species of Penicillium were recorded on the mallee leaves and only one (at very low frequencies) was recorded on mulga litter.

Experiments were undertaken to observe whether any major advantages in phosphorus nutrition were possessed by trees and shrubs which would react in their favour when compared with native grasses. All species studied (Acacia aneura, Cassia nemophila and Eucalyptus socialis) were highly responsive to increasing concentration of nitrogen and phosphorus and there was a very strong nitrogen x phosphorus interaction recorded in sand culture. However, growth rates and mean phosphorus absorption rates were much lower than those previously recorded for Australian semi arid grasses.

The relatively poor ground flora and the large volume of surface roots suggest both mallee and mulga communities operate on a tight extrinsic rather than intrinsic cycling of nutrients, although taken together the efficiency of both cycles could be high. In fact, the nitrogen and phosphorus cycle times in the semi-arid shrub/woodland ecosystems studied were quite comparable with those from more mesic environments. Furthermore, it was shown that mulga grassland is much less efficient in utilisation of phosphorus than endemic woodlands and could also require much larger amounts of nitrogen per unit of dry matter than competing woody plants.

It was concluded that grasses possess initial advantages in the establishment phase in these infertile semi-arid ecosystems, through faster growth rates and mean phosphorus adsorption rates. In time, competing woody plants develop a much larger root system which assists in drought survival and nutrient absorption. Concomitantly, the more efficient use of the limited available nutrients results in dominance by the woody plants.

Publications: BURROWS W.H. (1976b, 1986),

Regeneration and spatial pattern of *Acacia aneura* in south west Queensland (CLE-P50-WR(ii)).

Seed production from mulga in south west Queensland is adequate for regeneration. During summer, high soil temperatures (in addition to moisture deficits) may be a major factor limiting germination. Appreciable regeneration is occurring in both lightly stocked and unstocked areas, with or without summer rain. In thinned mulga scrubs, there was no significant difference in the number of seedlings regenerating under canopies of 40 and 160 trees ha^{-1}; but significantly fewer seedlings regenerated under 640 trees ha^{-1} canopies and in plots cleared of all trees.

The spatial patterns of mulga at one site were described and illustrated. All size classes (seedlings, <5 cm diameter and >5cm diameter at 30 cm height) exhibit strongly contagious distributions.

Environmental condition in south-west Queensland favour continual recruitment in mulga populations, as well as intermittent mass regeneration. Previous reports of only spasmodic regeneration occurring in mulga are due to stock browsing and killing seedlings in all but the most favourable seasons, rather than to an actual failure of seed to germinate and establish.

Publications:- BURROWS (1973a)

2. CONTROL OF WOODY SPECIES BY CHEMICAL AND OTHER METHODS

A considerable proportion (21 of 41 projects) of the early work undertaken on this project investigated the control of invading woody weed species in

the central west (based on Blackall) and the south west (based on Charleville).

A list of species investigated includes:

Common Name	Scientific Name
False sandalwood	*Eremophila mitchellii*
Butter bush	*Cassia eremophila*
Ellangowan	*Myoporum deserti*
Poplar Box	*Eucalyptus populnea*
Green Turkey bush	*Eremophila gilesii*
Silver cassia	*Cassia* spp.

A range of chemicals was used and the results of these (and other trials) are summarized in an advisory publication by Scanlan and Pressland (1984).

Control of the problem species of woody weeds is generally easy to obtain with chemicals. Unfortunately the cost is uneconomical, under the present cost structure, except for special purpose uses.

The need for continuing research into woody weed control, the investigation of the use of new chemicals and the extension of existing information is summarised by Burrows and Scanlan (1982).

Other control measures investigated included mechanical treatment (plowing) of Cassia, which was not successful, fire (superceded by Project W.R.T.F. DAQ03P) and the potential use of a native predator for biological control of green turkey bush (Eremophila gilesii). The native predator (a wingless grasshopper (Monistria discrepans (Walker)) produces only one generation per year, has natural predators and does not disperse readily. It is not suited for development as a biological control agent for green turkey bush.

Publications: ALLSOPP, P.G. (1976, 1977, 1978), BURROWS, W.H. (1965, 1971), BATIANOFF, G.N. and BURROWS, W.H. (1973), BURROWS, W.H. and SCANLAN, J.C. (1982) SCANLAN, J.C. and PRESSLAND, A.J. (1984).

3. MOISTURE RELATIONS IN SCRUB COMMUNITIES

Moisture utilisation of mulga under six ecological situations. (CLE-P50-WR

This project examined some structural relationships of mulga which enabled trees and forests to be categorized.

Throughfall, stemflow and interception increased linearly with precipitation. A higher proportion of rainfall was intercepted by large trees compared with small trees, while the proportion of throughfall and stemflow decreased with increasing tree size. The volume of stemflow waters was positively correlated with tree size. Interception decreased with increasing windspeed. Rainfall intensity did not significantly affect the stemflow or interception component though throughfall was shown to increase with increasing intensity for rainfall up to 6 mm aggregate.

Infiltration characteristics of the soil in close proximity to the trees were different from those further from the trunks. The part played by insects in aiding absorption of stemflow water was elaborated. Stemflow resulted in significantly deeper penetration of water close to trees than 2 or 4 m from their bases. The implications of the stemflow effects in terms of tree productivity are discussed.

The presence of as few as 40 trees ha^{-1} resulted in as great a soil water usage and extraction rate as in mulga forests as dense as 3600 trees ha^{-1}. Water use by ground storey vegetation on totally cleared sites was lower than on areas supporting 40, 160, 640 and 3600 trees ha^{-1}. The results, indicated that, within 70 days of rain sufficient to fully recharge the soil profile, soil water content is at or below permanent wilting percentage throughout the rooting zone. Evapotranspiration rates ranged from 0.3 mm d^{-1} when soil moisture was limiting, to 7.6 mm d^{-1} immediately following effective rainfall. The ratios of evapo-transpiration to pan evaporation range between 1.05 and 0.05 in summer, and between 1.33 and 0.04 in winter, the ratios being higher during the above average rainfall year 1973, than during the below average year 1972.

Thinning of mulga communities resulted in increases in the light intensity at ground level and increases in the quantity of rain available for soil water recharge.

The rooting habits of both mulga and the prevalent grass species Aristida jerichoensis were studied. The high density of roots of both species in the surface 30 cm of soil, and the depth of root penetration (> 135 cm), allowed these species to make use of light rainfall and also to tolerate drought by the potential ability to extract water stored at depth in the soil.

Ground storey production increased with decreasing tree density. Areas cleared of trees produced more grass and herbs (both numbers and quantity) than areas supporting 40, 160, 640 or 3600 trees ha^{-1}.

The productivity of wiregrasses (Aristida spp.), abundant and of low value in mulga lands, was observed on one field site under soil water conditions adequate for growth. Maximum growth rate in summer was 92 kg DM ha^{-1} d^{-1} winter rates were 10% of this. Maximum herbage produced in November to February (summer) was 3600 kg ha^{-1}, compared with 570 kg ha^{-1} in April to June (winter). Standing root crop in mid-summer was 1065 kg ha^{-1}. Because of their potential to rapidly produce a large biomass above ground and new inflorescences within 30 days after rain, wiregrasses will continue to be harmful species unless management techniques based on weaknesses in their life cycle are determined.

Mulga and grass seedling growth were affected by water stress and soil fertility. Increasing severity of water stress resulted in decreased top and root weights of mulga seedlings, but increased their root-shoot ratios. Root weights of mulga seedlings growing in phosphate deficient soils were lower than those grown in soil with adequate phosphorus. Mulga seedlings were capable of surviving with only 12.5 mm of rain per month, though germination did not occur unless at least 37.5 mm of rain occurs.

Growth rates of mulga were found to vary considerably. Mean daily wood and leaf weight increases of 0.74 ± 0.59 g m^{-2} d^{-1} and 0.26 ± 0.19 g m^{-2} d^{-1} respectively were calculated for a mulga forest of 3600 trees ha^{-1}.

Under adequate soil phosphorus conditions, water stress depressed top growth of the four grasses Anthephora pubescens, Aristida jerichoensis, Digitaria ammophila and Thyridolepis mitchelliana; depressed root weight of Aristida jerichoensis; increased root weight of Anthephora pubescens; and had no affect on root weights of the other two species. Root-shoot ratios of the four species increased with water stress, while tiller numbers decreased. Under limited soil phosphorus conditions, similar effects of water stress were exhibited by Anthephora, Aristida and Thyridolepis, though Aristida was affected to the greatest extent. Nevertheless, under these conditions top and root weights of Aristida were higher than those of the other two species.

Surface runoff was recorded from small plots in the mulga rangelands. Even small falls of rain (<15 mm) produced runoff equivalent to over 50% of the rain, but plant tussocks were instrumental in decreasing the number of rainfalls which generated runoff. Runoff was greater from the hard mulga and residual land zones than from the soft mulga zone. Regression and correlation analysis was used to identify topography, soil and vegetation factors influencing runoff. The maintenance of a perennial grass basal area of 2% was considered essential to reduce the loss of surface soil and nutrients.

Publications: PRESSLAND, A.J. (1972, 1973a, 1973b, 1974, 1975), 1976a, 1976b, 1981a, 1981 c), PRESSLAND, A.J. and LEHANE, K.J. (1977, 1980, 1982).

4. MISCELLANEOUS STUDIES

Surface micro-relief and vigour of mitchell grass (TRK-P3-WR)

A Mitchell grass stand containing marked denuded areas was surveyed on a 4.6 m grid, and scored according to vigour of the perennial grasses along the same grid. Low lying areas and areas with a low gradient supported only annual growth. Bulk densities and pH were taken of three pasture conditions: healthy Mitchell, annual growth between tussocks and in denuded areas. The percentage of available moisture varied from 22% in a healthy area, to 15% in a denuded area.

The significance of soil loss through land degradation to plant growth (CLE-- P86-WR)

Stability of mulga communities depends largely on the maintenance of surface litter (dead leaves, stems, wool, animal faeces) together with the first few centimetres of soil. Table 17 shows the effect of removing the surface 5cm and 10 cm of soil on subsequent nutrient levels in the available nutrient pool.

However, this is not the whole story. When the surface 5 cm is removed, the new surface 5 cm contains only 50% of the available phosphorus of the original surface soil. The situation would be considerably worse for young plant seedlings having a root depth less than 50 cm.

Table 17. Effect of removal of surface soil on subsequent soil fertility. A soil depth of 100 cm is assumed.

Depth of soil removed (cm)	Reduction (%) in			
	Total phosphorus	Available phosphorus	Total nitrogen	Organic carbon
5	7	13	9	11
10	14	20	16	19

Table 18 shows the relative production of plants growing in pots in three soils taken from around Charleville. Note that if the production of plants growing in soil taken from under mulga scrub at a depth of 0-5 cm is given as a value of 100, plants growing in soil taken from the same site but at a depth of 5-10 cm have only half that production. In other words, plant production mirrors soil fertility.

Table18. Plant growth in soil from two depths (0-5 cm and 5-10 cm) at three sites: under mulga scrub (UM), cleared mulga scrub (CM) and Mitchell grass (MG). Plant growth at the under mulga site (UM) and in soil taken from the soil surface (0-5 cm) is taken as 100. Note that growth is greatly reduced when the surface

layer is removed.

Soil depth (cm)	UM	CM	MG
0-5	100	93	206
5-10	50	41	69

Other effects of erosion of topsoil are:

- water use efficiency of plants decreases; plants produce less material from the same amount of water;
- infiltration of rainwater in the soil decreases; and
- runoff of rainwater over the soil surface, and consequently the probability of further erosion, increase.

Infiltration is increased and runoff decreased by:

- presence of ground cover, living and dead plants;
- roughness of surface, grass tussocks, fallen branches, rocks; and
- high organic matter content of surface soil.

Infiltration is decreased and runoff increased by:

- high soil moisture content;
- greater slope and slope length;
- soil compaction, often a result of running too many stock, particularly sheep; and
- high rainfall intensity and energy.

Erosion occurs through:

- raindrop splash; the impact of individual raindrops breaks down the soil structure and soil crusts impermeable to water may form and
- runoff.

The eroding force of runoff is directly proportional to:

- mass per unit of runoff water;
- runoff intensity; and
- length and gradient of slope;

and inversely proportional to:

- roughness of the surface.

Significance of these principles to the mulga country

A cover of mulga trees is beneficial because:

- raindrop velocity and consequently raindrop splash are decreased;
- infiltration is increased; and
- water penetrates deeper into the soil.

Surface litter (old plant parts, leaves, wood and the like) is beneficial because:

- raindrop splash is decreased;
- rate and quantity of surface water flow (runoff) are decreased;
- quantity of sediment in runoff water is decreased;
- retention of water by soil surface increases;
- infiltration capacity (amount of water soil can hold) is increased; and

- seed germination, seedling establishment and plant production are increased.

Conclusion

Present indications are that land degradation which is occurring in the mulga lands of Queensland can be reduced through changes in property management. Recommended procedures include:

- stocking mulga country at conservative rates, with due regard to the quantity of forage available to stock at the end of summer (80% of grass fodder is produced during summer);
- ensuring that the proportion of ground surface covered by the base of perennial grass (i.e. basal area) exceeds 2%. This may be achieved through adherence to the first point.
- reducing the number of stock during extended dry periods rather than attempting to feed mulga to all animals; and
- delaying restocking following drought at least until regenerating grasses have flowered to ensure a vigorous pasture.

Publications: PRESSLAND, A.J.(1985).

Gidgee scrub development survey (Bk1-P1-WR)

A survey was undertaken of the areas of gidgee scrub developed in the central west and of problems being experienced. This resulted in the early Blackall pasture work concentrating on control of woody weed species and on introduced pasture species (mainly buffel grass (*Cenchrus ciliaris*)).

5. INTEGRATION OF RESEARCH FINDINGS - MANAGEMENT RECOMMENDATIONS

Information obtained from this project has vastly improved the knowledge of how the plant communities of western Queensland function. It has highlighted the productivity relationship between woody vegetation and ground storey plants. It has drawn attention to the build up in woody weed populations which threaten that productivity. The role of chemicals in controlling these species has been shown to be effective but uneconomic. The need for alternative control measures (e.g. fire) has been highlighted.

Most of the mulga zone in Australia was occupied for use with domestic animals between 1850 to 1900 (Wilson and Graetz 1979). This period saw the introduction of cattle, sheep, horses, goats and rabbits. The provision of both surface and bore water points and subdivisional fencing has continued to the present. As part of the introduction of domestic animals, fire was actively discouraged in most of the area. (Beale, Orr, Mills 1985).

Expectations (of graziers, the public and governments) of the productivity of the land and the climatic conditions were moulded on European experience, as was property management. These expectations, and the anticipation that runs of above-average seasons represented "normal" conditions, led to over-estimation of the ability of the land to produce and to its subdivision into units that, in recent years, have proven to be too small to be economical. This has continued the economic pressure to stock beyond the ability of the land, and hence the degradation of resource. (More recently the effects of property size have been recognized and property amalgamations have been taking place).

The picture common to these areas is of increasing stock numbers for about 30 - 40 years following settlement, then a period of drought with heavy loss of livestock, the numbers of which have not regained their previous peak (Table 19). This pattern is not restricted to the mulga region and estimates of the drop in numbers are not available for it alone. There were also increases in populations of other animals (notably rabbits) while the number of domestic animals increasing.

McTaggart (1936) cited the carrying capacity of the south-west Queensland mulga country as one sheep to 2 hectares, which is about that of the best parts of the area now. This suggests that there has been continued decline in productivity, at least in some areas.

Table19. Period of settlement, period of devastating drought and stock numbers pre- and post-drought for several areas of arid Australia.

District	Year Settled	Drought Years	Numbers before Drought	Numbers after Drought
West Aust.[1]	1870's	1930's	20,800,000 sheep 1,500,000 cattle	1,400,000 sheep 75,000 cattle
Western Qd[2]	1860's	1902	11,000,000 sheep (1897)	9,000,000 DSE[4] (1957 peak since 1897)
Western N.S.W.[3]	1860's	1890's	15,500,000 sheep (1891)	6,000,000 sheep (1900)

[1] J.G. Morrissey (1984); [2] Western Arid Region Land Use Survey Area, Qd; [3] A.D. Wilson and R.D. Graetz (1979); [4] Dry Sheep Equivalent (calculated at 1 beast = 8 sheep).

These decreases in domestic animal carrying capacity were accompanied by:

Denudation of vegetation (both trees and ground storey)

Increased soil erosion by wind and water

Decreased moisture infiltration and increased run-off

Decreases in more desirable plant species

Increases in less palatable plant species

Increases in annuals and decreases in perennials.

Results obtained from this project, combined with those from other research projects undertaken in the area (K/2/900(C)), have allowed the education of people concerned with the region (researchers, extension personnel, graziers and land administrators) and the development of management strategies for the region.

Pressland (1976) addressed the effects of removal of mulga on rangeland stability. Even ten years after thinning, ground storey vegetation is still in a state of flux. Management can markedly influence pasture composition and mulga regeneration. Poor rangeland management may lead to reductions in basal area sufficient to reduce productivity and accelerate degeneration through soil and nutrient losses in run-off water. Mills (1981) discussed land degradation in the mulga lands of far south-west Queensland in relation to the extended drought periods which occur in the area. Pressland (1981, 1984) found that stocking rates in mulga country were similar to those in mitchell grass country, despite much larger levels of pasture biomass in the latter. Both he and Mills (1981) developed the theme that maintenance of stock numbers on mulga country during extended dry periods, and restocking too rapidly at the end of a drought is biologically unsound. An alternative approach outlines the need for financial incentives to encourage sound biological practices and for government assistance in the search for, and finance of, additional areas for small land-holders.

Burrows (1979) concluded that the central requirements for sound vegetation management in Queensland's semi-arid sheeplands are firstly, a realistic appraisal of the environment, and secondly, sufficiently large enterprises to favour conservative stocking policies (legislatively enforced if necessary). Inherent in this concept is the ability to lighten grazing pressures (at times of nutritional stress) and to increase them by adjustment of paddock size (for shrub control). In the latter case the choice between winter and summer grazing may also be important. Present knowledge of the autecology and reaction to grazing of the vast majority of plants in these ecosystems is poor, and until this is overcome, under-rather than over-utilization should be encouraged.

Burrows (1980) reviewed range management in the dry tropics of Queensland and listed some management principles that apply to animal production in these areas:-

(i) Environmental determinants of animal production.

* Rainfall variability in amount and effectiveness is the primary factor limiting pasture growth and hence animal production.

* Ninety percent of potential grass production in mulga pastures occurs in the October-March period.

* Mitchell grass soils are inherently fertile while mulga soils are quite infertile, being characterized by a strongly acid profile, low nutrient availability (notably phosphorus) and surface sealing which contributes to significant rainfall run-off.

* Woody plants tend to dominate rangelands, especially on infertile soils. As the environment becomes harsher,shrubs will tend to dominate rather than trees, where the physiologically more efficient life form of the shrub is needed for persistence.

* In induced grasslands or savanna there is an inverse curvilinear relationship between woody plant density and pasture yield. Unlike higher rainfall regions, many of the trees and shrubs of the inland are important sources of browse for domestic animals.

* Surface water is generally not a problem in Mitchell grass (in most seasons) and mulga systems and the underlying artesian basin ensures relatively even use of these rangelands.

(ii) Managerial determinants of animal production.

* Pasture stability and animal productivity on semi-arid rangelands are affected by many factors such as soils, vegetation type, rainfall, stocking pressures, industry economics etc. Of these factors the most readily manipulated by the grazier are concerned with his stock e. g. types of animals being grazed, stocking pressures and time of shearing.

* Stock numbers should be adjusted to the feed available. In practice this means that carrying capacity is determined largely by the numbers that can be safely carried in poor seasons.

* Animal production as opposed to liveweight maintenance is largely influenced by the availability and accessibility of broad-leaved plants ("nutrient accumulators") in the pasture.

* The need to improve animal productivity has to be balanced against the need to promote stability through the maintenance of a high proportion of perennial grass in the pasture. There is clear evidence that interseasonal variation is markedly greater where the vegetation is comprised of mostly annual species. For this reason, along with the difficulty of establishing grass species on infertile soils, basal area will generally override composition as the principal determinant of grassland condition (Christie 1978b).

* Utilization levels should be adjusted so that consumption does not exceed about 20 percent of end-of -summer production in mulga grasslands and 40 percent of this in Mitchell grasslands. In practice, stocking levels should be such that 12 months after grass growing rain has fallen there is still a good coverage of stubble on the pasture. There is little evidence that rotational or other grazing systems in Australian rangelands improve vegetative cover or animal production over continuous grazing systems (Wilson 1977). By corollary, as far as it is practical, animals should be segregated within herd or flock structures but allowed freedom of movement within uniform land units.

* The minimum requirement of animal management is disease and parasite control. Mineral supplementation is beneficial in certain situations but it is not a panacea to nutritional stress in mulga and Mitchell grass systems.

These management principles have been further discussed in Harrington et. al. (1984), Orr and Holmes (1984), Pressland (1984, 1985), Wilson et. al. (1984), Holmes (1985) and Sullivan et. al. (1985).

Publications: BOYLAND, D.E. and MILLS, J.R. (1976), BURROWS, W.H. (1976, 1979, 1980), BURROWS. W.H. and BEALE, I.F. (1976), HARRINGTON , G.N., MILLS, D.M.D., PRESSLAND, A.J. and HODGKINSON, K.C. (1984), MILLS, J.R. (1981, 1982), PRESSLAND, A.J. (1975, 1976, 1981a, 1981b, 1984, 1985), ROBERTS, B.R. (1975), SILCOCK, R.G. (1981), SULLIVAN, M.T., DAY, J.R.,CLARKE, M.R. and DUNLOP, E.B. (1985), WILSON, A.D., HARRINGTON, G.N. and BEALE, I.F. (1984).

E. REFERENCES

ALLSOPP, P.G. (1976). Studies in the ecology of *Monistria discrepans* (Walker) (Orthoptera: Pyrgomorphidae) in southern Queensland. M.Agr. Sc. Thesis, Univ.Qd.

ALLSOPP, P.G. (1977). Biology and capacity for increase of *Monistria discrepans* (Walker) (Orthoptera: Pyrgomorphidae) in the laboratory. *J. Aust. Ento. Soc. 16*: 207-213

ALLSOPP, P.G. (1978). Seasonal history, hosts and natural enemies of *Monistria discrepans* (Walker) (Orthoptera: Pyrgomorphidae) in south-west Queensland. *J. Aust. Ento. Soc. 17*: 65-73.

AUSTIN, M.P. (1981). Permanent quadrats: an interface for theory and practice. *Vegetatio 46*: 1-10.

BATIANOFF, G.A. and BURROWS, W.H. (1973). Studies in the dynamics and control of woody weeds in semi arid Queensland. II. *Cassia nemophila* and *C. artemisiodes. Qd. J. Agric. Anim. Sci. 30*: 65-71.

BEALE, I.F. (1970). Influence of mulga (*Acacia aneura* F. Muell.) tree density on leaf fall and herbage production. *Proc. 3rd Aust. Arid Zone Conf.* Broken Hill pp 6.26-6.28.

BEALE , I.F. (1971). The effect of thinning on the productivity of two mulga (*Acacia aneura* F. Muell) communities in south western Queensland. M.Agr.Sc.Thesis, Univ. Qd.

BEALE, I.F. (1973). Tree density effects on yields of herbage and tree components in south west Queensland mulga (*Acacia aneura* F. Muell.) scrub. *Trop. Grasslds. 7*: 135-142.

BEALE, I.F. and BURROWS, W.H. (1968). Productivity of mulga scrubs in south west Queensland. *Aust. Grassland Congr. Section 2b*: 24-25.

BEALE, I.F. and BURROWS, W.H. (1970). Density of native grasses in mulga communities of south west Queensland. *Proc. 3rd Aust. Arid Zone Conf.*, Broken Hill pp 6.27-2.68.

BEALE, I.F., ORR, D.M. and MILLS, J.R. (1985). Pastoral impacts on the ecosystem. Proc. Mulga Symp., Roy. Soc. Qd., Brisbane.

BURROWS, W.H. (1965). Woody weeds on run-on and run-off areas in south west Queensland. *Proc. 2nd Aust. Arid Zone Conf.* Alice Springs. pp C16-17.

BURROWS, W.H. (1971). Studies in the ecology and control of green turkey bush (*Eremophila gilesii* F. Muell.) in south west Queensland. M.Agr. Sc. Thesis, Univ. Qd.

BURROWS, W.H. (1972). Productivity of an arid shrub (*Eremophila gilesii*) community in south west Queensland. *Aust. J, Bot. 20*: 317-29.

BURROWS, W.H. (1973a). Regeneration and spatial patterns of *Acacia aneura* in south west Queensland. *Trop. Grasslds 7*: 57-68.

BURROWS, W.H. (1973b). Studies in the dynamics and control of woody weeds in semi arid Queensland. I. *Eremophila gilesii. Qd J. Agric. Anim. Sci. 30*: 57-64.

BURROWS, W.H. (1974). A study of the phenology and germination of Eremophila gilesii in semi arid Queensland. In: "Plant morphogenesis as the basis for scientific management of rangelands." Proc. U.S. - Australian Workshop, Berkeley. U.S.D.A. Miscl. Publ. No. 12171 150-59.

BURROWS, W.H. (1976a). Condition assessment of woodland/shrubland. In "Native pasture methods workshop". Qd Dept Prim. Ind. Mimeo.

BURROWS, W.H. (1976b). Aspects of nutrient cycling in semi-arid mallee and mulga communities. Ph.D. Thesis, Aust. Nat. Univ..

BURROWS, W.H. (1979). Vegetation management decisions in Queensland's semi-arid sheeplands.In: "Rangeland ecosystem evaluation and management", (Ed. Howes, K.M.). Aust. Rangel. Soc.

BURROWS, W.H. (1980). Range management in the dry tropics with special reference to Queensland. Trop. Grasslds 14: 281-87.

BURROWS, W.H. (1985). Potential ecosystem productivity. Proc. Mulga Symp., Roy. Soc. Qd. November 1985. Brisbane.

BURROWS, W.H. and BEALE, I.F. (1969). Structure and association in the mulga (Acacia aneura) lands of south western Queensland. Aust. J. Bot. 17: 539-552.

BURROWS, W.H. and BEALE, I.F. (1970). Dimension and production relations of mulga (Acacia aneura F. Muell.) trees in semi arid Queensland. Proc. 11th Intl Grassld Congr., Surfers Paradise, Australia. pp 33 - 35.

BURROWS, W.H. and BEALE, I.F. (1976). Techniques for studying vegetation in the semi-arid pasture zone. In: "Native pasture methods workshop". Qd Dept Prim. Ind. Mimeo.

BURROWS, W.H. and SCANLAN, J.C. (1982). Report on regrowth problems - central western Queensland. Qd Dept Prim. Ind. Mimeo.

BURROWS, W.H., BEALE, I.F., SILCOCK, R.G. and PRESSLAND, A.J. (1984). Prediction of tree and shrub population changes in a semi arid woodland. In "Ecology and management of the world's savannas". (Eds Tothill, J.C. and Mott, J.J.). Aust. Acad. Sci., Canberra.

CHRISTIE, E.K. (1978a). Ecosystem processes in semi-arid grasslands. I. Primary production and water use of two communities possessing different photosynthetic pathways. Aust. J. Agric. Res. 29: 1-15.

CHRISTIE, E.K. (1978b). Herbage condition assessment of an infertile semi-arid grassland based on site production potential. Aust. Rangel. J. 1: 87-94.

CONDON, R.W., NEWMAN, J.C. and CUNNINGHAM, G.M. (1969). Soil erosion and pasture degradation in central Australia. I. Soil erosion and degradation of pastures and top-feed. J. Soil Cons. Serv. N.S.W. 25: 47-92.

EVERIST, S.L., HARVEY, J.M., and BELL, A.T. (1958). Feeding sheep on mulga. Qd Agric. J. 84: 352:61.

HARRINGTON, G.N., MILLS, D.M.D., PRESSLAND, A.J. and HODGKINSON, K.C. (1984). Management of semi-arid woodland ecosystems. In: "Management of Australia's rangelands". (Eds Harrington, G.N., Wilson, A.D. and Young, M.D.) C.S.I.R.O..

HEADY, H.F. (1975). Rangeland management. McGraw Hill, New York.

HOLMES, W.E. (1985). Economic aspects of mixed sheep and cattle grazing in western Queensland mulga. Proc.Mulga Symp., Roy. Soc. Qd., Brisbane.

JAMESON, D.A. (1967). The relationships of tree overstorey and herbaceous understorey vegetation. J. Range Manage. 20: 247-49.

JOHNSON, R.W. and BURROWS, W.H. (1981). Acacia tall open forests, woodlands and shrublands. In: "Australia Vegetation" (Ed Groves, R.H.). Cambridge Univ. Press: London.

McTAGGART, A. (1936). A survey of the pastures of Australia. C.S.I.R. Bull. 99.

MILLS, J.R. (1981). Land degradation and drought relief measures in the mulga lands of western Queensland. Proc. 3rd Bienn. Conf., Aust. Rangel. Soc., Alice Springs.

MILLS, J.R. (1982). Pastoralism in south west Queensland. In "Focus on Australia's arid lands", Broken Hill. Aust. Conserv. Found..

MILLS, J.R. (1982b). Land degradation in the arid zone of Queensland - Interim Report. Qd Dept Prim. Ind., Charleville. Mimeo.

MORRISSEY, J.G. (1984). Arid mulga woodlands. In "Management of Australia's rangelands". (Eds Harrington, G.N., Wilson, A.D. and Young, M.D.). C.S.I.R.O., Melbourne.

NEWMAN, J.C. and CONDON, R.W. (1969). Land use and present condition. In: "Arid lands of Australia". (Eds Slatyer, R.O. and Perry, R.A.). A.N.U. Press, Canberra.

ORR, D.M. (1981). Changes in the quantitative floristics in some Astrebla spp. (mitchell grass) communities in south west Queensland in relation to trends in seasonal rainfall. Aust. J. Bot. 29: 533-45.

ORR, D.M. and HOLMES, W.E. (1984). Mitchell grasslands. In: "Management of Australia's rangelands". (Eds Harrington, G.N., Wilson, A.D. and Young, M.D.). C.S.I.R.O., Melbourne.

ORR, D.M. and EVENSON, C.J.(1985). Influence of rainfall and grazing on the vegetation dynamics of a semi-arid grassland in south west Queensland. In: " Ecology and management of the world's savannas". (Eds Tothill, J.C. and Mott, J.J.). Aust. Acad. Sci., Canberra.

ORR, D.M. (1986). Factors affecting the vegetation dynamics in Astrebla grasslands. Ph.D. Thesis, Univ. Qd. (Submitted).

PRESSLAND, A.J. (1972). Micrometeorological observations in a desert woodland (Acacia aneura F. Muell.) in south western Queensland. M.Sc. Preliminary Thesis, University of New England.

PRESSLAND, A.J. (1973a). Rainfall partitioning by an arid woodland (Acacia aneura F. Muell.) in south western Queensland. Aust. J. Bot. 21: 235-45.

PRESSLAND, A.J. (1973b). Soil moisture distribution and evapo-transpiration of mulga (Acacia aneura F. Muell.) scrubland in south western Queensland. In: "Studies of the Australian Arid Zone Symposium III - Water in Rangelands", Alice Springs, October 15-18, 1973.

PRESSLAND, A.J. (1974). Redistribution of precipitation, water use and productivity of thinned mulga (Acacia aneura F. Muell.) communities in south western Qd. M. Sc. Thesis, Univ. New England.

PRESSLAND, A.J. (1975). Productivity and management of mulga in south western Queensland in relation to tree structure and density. Aust. J. Bot. 25: 965-76.

PRESSLAND, A.J. (1976a). Effect of stand density on water use of mulga (Acacia aneura F. Muell.) woodlands in south western Queensland. Aust. J. Bot. 24: 177-91.

PRESSLAND, A.J. (1976b). Soil moisture redistribution as affected by throughfall and stem flow in an arid zone shrub community. Aust. J. Bot. 24: 641-649.

PRESSLAND, A.J. (1976c). Possible effects of removal of mulga on rangeland stability in south western Queensland. Aust. Rangel. J. 1: 24-30.

PRESSLAND, A.J. (1981a). Drought and the mulga lands of Queensland. Proc. 3rd Biennial Conf., Aust. Rangel Soc., Alice Springs, pp. 168-173.

PRESSLAND, A.J. (1981b). Woody weeds in Australian rangelands: Is prevention easier than cure? Proc. 6th Aust. Weeds Conf., Gold Coast, Sept 1981.

PRESSLAND, A.J. (1981 c). Runoff and the ameliorating effect of plant cover. Proc. 3rd Bienn. Conf. Aust. Rangel. Soc. , Alice Springs, September 23-24, 1981. pp. 49-52.

PRESSLAND, A.J. (1984a). Vegetation dynamics in semi-arid woodland ecosystems. Proc. 2nd Intl Rangel. Conf., Adelaide, May 1984.

PRESSLAND, A.J. (1984b). A review of the productivity and management of western Queensland"s rangelands. Aust. Rangel. J. 6: 28-45.

PRESSLAND, A.J. (1985). Land degradation in the mulga lands: processes and consequences. Qd. Agric. J. 111: 113-15.

PRESSLAND, A.J. and LEHANE, K.J. (1977). Runoff from natural and simulated rainfall in the mulga communities of south western Queensland. Proc. 2nd Bienn. Conf. Aust. Rangel. Soc. , Broken Hill, July 8, 1977 pp. 147-160.

PRESSLAND, A.J. and LEHANE, K.J. (1980). Run-off from natural and simulated rainfall in the mulga communities of south western Queensland. Aust. Rangel. J. 2: 217-221.

CLE-P47-WR	Studies on the ecology of green turkeybush: Selected sites in south west Queensland (i) Australian and Queensland distribution (ii) Description of detailed study sites (iii) Structural attributes of _Eremophila gilesii_ communities (iv) Functional dynamics of _Eremophila gilesii_ communities (v) Interaction between structure and function (vi) Temporal change in structure and function (vii) Reproduction, germination and seedling growth (viii) control	WHB,BJC	1970	Published
	(ix) Biological control with _Monistria pustulifera_	PGA		
CLE-P50-WR	Moisture utilization of mulga under six ecological situations	AJP	1970	Published
	Regeneration of mulga in artificially thinned communities-seed production, germination requirements and regeneration frequency (also in CLE-P6-WR)	WHB,BJC	1972	Published
CLE-P64-WR	Nutrient cycling in semi-arid woodlands. Adaptation of trees and shrubs to infertile semi arid soils Nutrient cycling in woodlands (I) Aspects of nutrient cycling in mallee and mulga communities	WHB	1974	Published
CLE-P85-WR	Miscellaneousherbicidestudies	AJP,DCC	1981	Published
CLE-P86-WR	The significance of soil loss through land degradation to plant growth	AJP,DCC	1983	Published

BLACKALL PROJECTS

BKL-P1-WR B	Gidgee scrub development survey	DLP	1962	Reported
BKL-P2-WR B	Hormone spraying of _Eremophila mitchellii_ I.Wehl,"Clarendon"	DLP	1962	Published
BKL-P3-WR B	Hormone spraying of _Eremophila mitchellii_ D. MacNichol, "Inverness"	DLP	1962	Published
BKL-P5-WR B	Mechanical treatment of _Eremophila mitchellii_. D. MacNichol, "Inverness"	DLP	1962	Published
BKL-P6-WR B	Carbohydrate reserves of _Eremophila mitchellii_. G. MacKenzie, "Mineeda"	DLP	1962	Abandoned
BKL-P7-WR B	Hormone spraying of _Cassia eremophila_ "Gillespie"	DLP	1962	Published

BKL-P8-WR B	Hormone spraying of *Eucalyptus* P. Connell, Alpha	DLP	1962	Published
BKL-P12-WR	*Eremophila mitchellii* control J.Legge, Listowel Rd	DLP	1962	Published
BKL-P15-WR	Misting trials on *Cassia eremophila* N.McClymot, "Linden"	DLP	1962	Published
BKL-P16-WR	Basal treatment on *Eremophila mitchellii* R.Lane, "Swaylands"	DLP	1962	Published
BKL-P24-WR	Frill treatment for *E. mitchellii* control	DLP	1962	Published
BKL-P25-WR	Cut stump and poison treatments on sandal-wood	DLP	1962	Published
BKL-P26-WR	Basal spraying on sandalwood-Swaylands	DLP	1964	Published
BKL-P27-WR	Basal spraying on big sandalwood	DLP	1964	Published
BKL-P28-WR	High volume spraying of small sandalwood	DLP	1964	Published
BKL-P30-AG	Misting of sandalwood J.Legge, "Fairlea"	DLP	1964	Published
BKL-P44-AG	Misting of butterbush N.McClymot, "Linden"	DLP	1964	Published
BKL-P47-WR	Spread of *Cassia* on a water-spreader	WHB	1965	Published
BKL-P53-WR	Rangeland condition and trend	DMO,CJE	1972	Published

TOORAK PROJECTS

TRK-P3-WR B	Surface micro-relief and vigour of mitchell grass	JP	1968	Reported

RICHMOND PROJECTS

RMD-P8-WR B	Exclosure-Toorak	EJW	1963	Reported

OFFICER ABBREVIATION CODE

RW	R. Wilson
JE	J. Ebersohn
WHB	W.Burrows
IFB	I.Beale
RGS	R.Silcock
FTS	Flora Smith
JO'D	J.O'Donnell
LW	Lyn (Corbett) Williams
EKC	E. Christie
JC	J. Cull
CJE	C. Evenson
DCC	D. Cowan
PJR	P. Rowen
GNB	G. Batianoff
TT	T. Telford
AJP	A. Pressland
JD	Janelle Day
DMO	D.Orr
JFC	J. Clewett
MTS	M. Sullivan
JCS	J. Scanlan
EA	E. Anderson
GG	G. Graham
PSB	P. Bowly
KJL	K. Lehane
DLP	D. Purcell
GL	G. Lee
GP	G. Payne (S&W, Blackall)
JP	J. Peart
BJC	B. Caffery
NMcM	N. McMeniman(S&W, Charleville)
JR	J. Rickman
PGA	P. Allsopp(ENTO, Toowoomba)
PCS	P. Smith(BCH, Richmond)
DN	D.Niven(S&W, Charleville)
DJ	D. Jordan(S&W, Charleville)
JM-J	J. Mander-Jones

FINAL REPORT PHOTOGRAPHIC SUPPLEMENT

GRAZING LAND PRODUCTIVITY AND STABILITY

(K/2/900 (B))

GENERAL VIEWS OF EXCLOSURE SITES

(Cle P2 WR)

Queensland Department of Primary Industries

1986

Site 4. WITTENBURRA July 1974. A very good season.

Site 4. WITTENBURRA July 1973. A dry year.

Site 3. MONAMBY September 1973

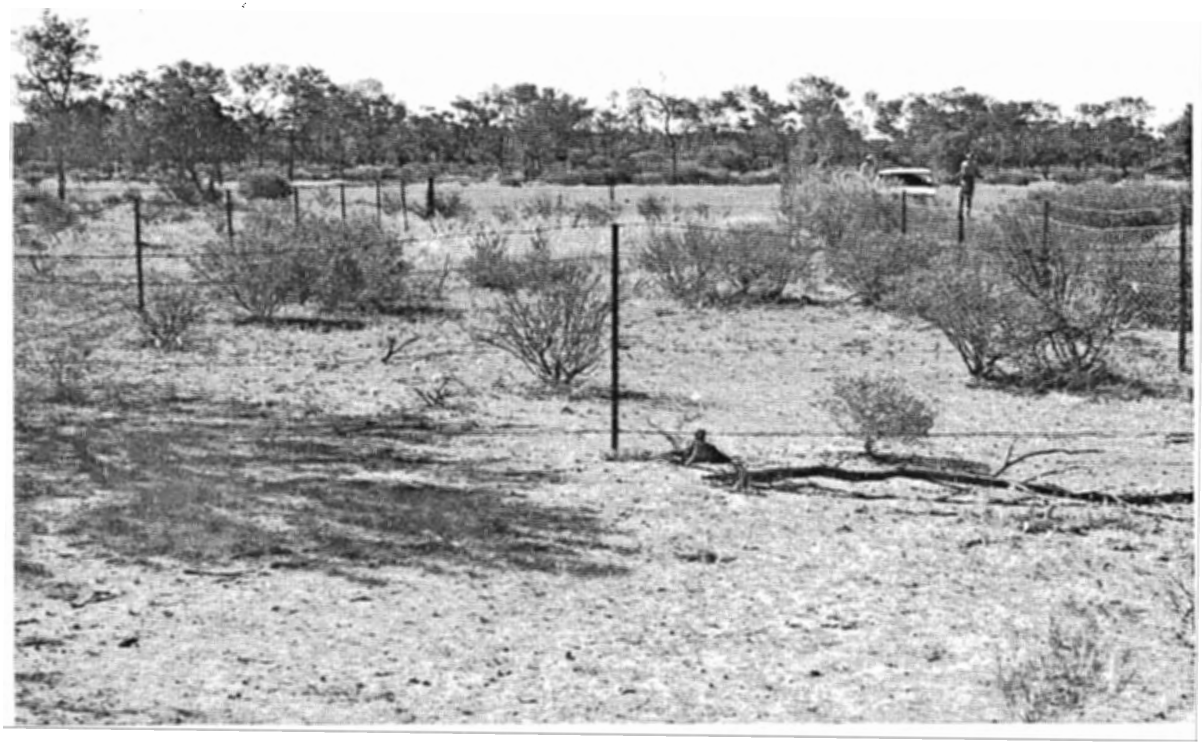
Site 2. BOATMAN March 1973

Site 6. MAXVALE March 1973

Site 7. LANHERNE July 1973

Site 1. LESDALE March 1973

Site 5. TURN TURN July 1973



Site 17. KOONAWALLA May 1973

Site 8. MIDDLETON July 1973

Site 16. WONGALEE FARM March 1973

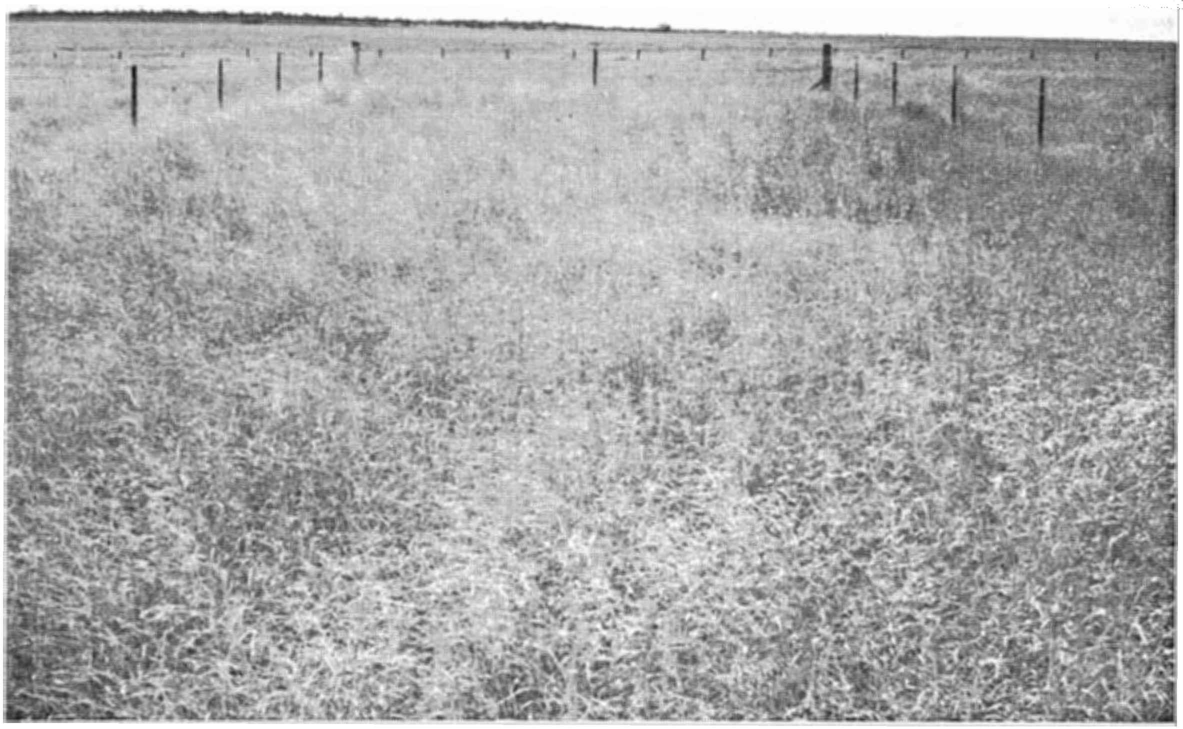
Site 15. WONGALEE March 1973

Site 12. BOOTHULLA May 1973.

Site 14. BAYSWATER July 1973

Site 11. NULLA October 1983

Site 13. WILLACORA March 1974



Site 10. STIRLING DOWNS July 1973.

Site 9. AIRLIE March 1984