Managing rangeland vegetation with fire
annotated bibliography

**Abstract:** This paper sets out a framework for analysing rangeland regions in industrialised democracies. I base the framework on Australian experience and recognise the influence of regional political ecology. I refer to US rangelands. I ignore those in other industrialised countries but believe the concepts I use are general, though conclusions about specific countries will differ. Concepts are drawn from 'complex adaptive systems'. I begin with an explanation and justification of the approach. A brief history of the rangelands follows. I then develop a general complex adaptive system model for rangelands in the US and Australia. Next I outline the development of an adaptive strategy for rangelands, using a case study from NSW. I finish the paper by setting out a research agenda promoting the need for fundamental research on complex adaptive systems, and for a program of applied research in which past and continuing disciplinary studies are integrated within a complex adaptive system framework.


**Notes:** The topography of the western division is gentle with only few mountain ranges, there is a wide variety of landscapes in various combinations of soils, topography and vegetation varying from flat tree less plains to parallel sand ridges, to dense timber and scrubland steep hills and ranges. Each landscape provides different fuel types, and access problems often compounded by poor water supplies.

There were relatively few fires cf the 74/75 & 76/77 seasons due to lack of fuel because of drought.


**Notes:** *Shrub encroachment and control:* Shrub encroachment may be a symptom rather than a cause of poor rangeland condition; shrub control needs to be approached from a total management perspective; Holistic resource management - considers that any decision on land management must include all factors re ecosystem and management; shrub management may be more realistic than shrub control - suppress regrowth rather than attempt to eradicate it; Integrated Brush Management Systems developed in Texas - involves
integration of available control techniques into a comprehensive programme; overgrazing appears to universally increase the rate of encroachment; encourage pasture vigour; use browsers (goats) to control shrubs only when grass at its lowest level of acceptability; ineffective treatment of shrubs is often worse than no treatment at all; priority areas for control - highest potential production, least soil erosion risk, greatest shrub density; grazing management in shrub control needs further investigation; need to understand succession of shrubs and pasture species is essential for effective management; chemical may be more useful with new products

*Rangeland condition and grazing management:* overgrazing more due to how long area is grazed rather than number of animals; when different livestock are grazing in the same area each one concentrates more on its priority selection; short duration grazing may be useful to degraded pastures or maximising small areas of high production; residual levels of vegetation rather than livestock numbers may be a better criterion for grazing management - especially for perennial pastures; need to account for TGP.

*Land use and management:* In USA most damage caused in first 20 years and a serious lack of ecological understanding; whole property planning is essential; need to include landholder participation in development of land management plans; co-operation is more effective than the threat of forfeiture

*Fire:* prescribed burning useful to prevent wildfires where fuel build up occurs.


**Abstract:** A fire management strategy for Uluru (Ayers Rock - Mt Olga) National Park was developed by CSIRO in 1982. The strategy aims to reintroduce a mosaic of patch burns, similar to those imposed by traditional Aboriginal people, that will disrupt the flow of the inevitable wildfires in spinifex grasslands. After six years of fire management we have assessed the ability of the patch burns to inhibit the spread of wildfires and to promote habitat diversity. An effective mosaic of patch burns within the park for wildfire protection has not yet been created. The management burns have been too few and too small. However the patches are effectively increasing localised species richness and Park biotic diversity by providing a variety of post-fire successional states in the vegetation. The Park managers now have the opportunity to improve the use of fire as an effective management tool.

**Notes:** There has been an annual increase in the number of management burns as the park staff become more confident with using it as a tool.

Abstract: Spinifex grasslands cover more than 25% of the Australian landscape. Spinifex is a generic term that includes three genera and over 60 species of perennial hummock grass. The grasses occur on soils that are low in nutrients and in climatic regions that are typically arid or semi-arid. Fuel accumulation is strongly linked to the post-fire cumulative rainfall and time since fire. The interval between fires can range from less than 3 years to more than 30 years. In the past aboriginal burning is thought to have reduced the size and increased the frequency of fires in spinifex grasslands. These days, fires can be extremely large, commonly covering many thousands of square kilometres. Data are presented that describe the frequency, extent and patchiness of fires in spinifex grasslands that extend along a climatic gradient from the Great Victoria Desert to Arnhem Land. Fire has a pronounced effect on the distribution of plants and animals. Although the evidence that a changed fire regime has led to a decline in medium-sized mammals is equivocal, there is also strong evidence that the presence of mature spinifex is important to the maintenance of plant and animal species richness and diversity. Large fires in the spinifex ecosystems are contributing to a decline in the distribution of ‘fire-sensitive’ plants such as mulga (Acacia aneura) in certain areas. Further research needs to more clearly determine the size and frequency of fires that best suit animals and plants with particular life history characteristics, but active management programs are required immediately. Remote sensing technology should be used to effectively monitor fire extent and pattern in the extensive spinifex dominated landscapes and these data are needed to formulate fire management plans.

Notes: Points out the different perspectives re fire in the landscape: Aboriginal people were traditionally burners while European people have a deep seated need to control and suppress fire. Uncertainty exists as to the past & existing patterns of fire in spinifex grasslands and the relative attitudes of these two inhabitants of the land are changing with younger aboriginal people adopting a more conservative approach while conservationists are advocating greater use of fire. The need to understand the consequences of different fire regimes, especially while there is still some Aboriginal knowledge present.

Fuels in spinifex grasslands: Once established the perennial spinifex hummocks accumulate biomass after major rainfall events and it remains. Early post-fire spinifex cover and biomass are low with high plant species diversity responding to reduced competition and increased nutrients. Fuel is low and, depending on rainfall may persist up to 15 years but when rainfall high sufficient fuel can accumulate to burn twice in 3 years.

Fire regimes: Fire intensity is most strongly affected by fuel load and rate of spread. Fuel loads can reach 13t/ha in the desert regions to 40t/ha on Kakadu sandstone escarpments. Seasonality has been little studied but varies widely

Fire size and extent: This is the area burnt by a single fire. Depends on continuity and homogeneity of the fuel, fuel moisture content and weather conditions. Homogeneity affected by features that affect growth of the spinifex such as substrate, habit and antecedent
rainfall.

*Fire Interval:* The time between successive fires at the same location. Map of fire frequency shows variation across the NT.

In non-spinifex arid Australia fires are less frequent and the fuel is from non-spinifex grasses & forbs (annuals & perennials). Big fires can only occur about a year after a sequence of high rainfall events as fuel loads diminish due to grazing or decomposition. Smaller fires can occur soon after single effective rainfall events.

*Fire patchiness:* Heterogeneity of fire ages within a region and this is very important for objectives of most fire management programmes, aimed at reducing the occurrence of extensive wildfires - patch burning - creation of low fuel zones which will disrupt wildfire spread. The patchiness of a single fire depends on the continuity and homogeneity of fuel related to time since last fire and accumulation rate of fuel. Soil and landform characteristics can also cause patchiness.

*Fire sensitive plant communities:* Spinifex grasslands often include or are adjacent to fire sensitive acacia woodlands (lancewood, mulga, Undoolyana wattle) and fires that commonly start in spinifex communities can severely affect these communities. Changes in the balance between spinifex and mulga communities have been observed in the Pilbara region of WA where it is postulated that in the absence of aboriginal burning, large areas of mulga woodland are being replaced by spinifex dominated communities.

*Animals:* Clear trends have emerged from a number of vertebrate studies - some species prefer immediate post burn habitats while others are only found in long unburnt spinifex (Uluru Fauna Survey, Masters, Southgate, Tanami fire study) - the richness of mammal and reptile species was generally greater in mature spinifex than recently burnt habitat. Further, rainfall has a highly significant and interactive effect on the response of the animals to fire. Nomadic birds were most abundant in recently burnt patches after heavy rains that promoted vigorous growth of ephemeral plants. Overall the changes brought by exceptionally large rainfall events far exceed those produced by fire in isolation.


**Notes:** This is the most comprehensive study of the ecology and history of the cypress forests of the central west, providing a detailed analysis of ecological cycles and the influence of disturbance by natural forces or management, edaphic factors etc.

The appearance of dense pine scrub across many areas in this part of the colony occurred in the late 1870’s and early 1880s. The region was being overcome by rabbits by the 1890’s. The forest reserves of the 19th century were mixed stands of pine (some large and >>100 years old), box and Casuarina. Today’s forests are largely the product of the past 50 years dominated by young pine, few box and oak.

Records of the early explorers including botanist Allan Cunningham described the early 19th century landscape as a mosaic of plains ‘scrubs’ and open and dense forests (including cypress
from young regrowth to mature trees).
The natural cypress life cycle is probably 200 to 300 years from dense regrowth to individual old trees but the cycle can be compressed to 100 years using forestry practices. All three pine forests examined contain vastly fewer hardwoods than pre-European forests.

1880’s – concern being expressed at the depletion of useful fodder trees in western NSW – Govt moved to control ringbarking on crown lands “stop ‘wanton and reckless waste of 1st class timber’. Very important observations by early explorers – vegetation in the area north of the Lachlan varies considerably over quite short distances.

Land occupation – from 1835/40 very sparse occupation – 1870’s huge sheep numbers. Early 1880’s – dense scrub growth mostly pine on lands that were reputedly open box, kurrajong and scattered large pines, 1950’s+ - massive pine regeneration (+ rain – rabbits); culling (ringbarking and felling) mostly eucalypts and pines and casuarina carried out sporadically in cypress forests over the last 60 years, especially in the late 1960’s and early 1970’s.

Back Yamma 1881 – cypress scarce as building timber, large quantity small pine and large trees and plenty box – many thousands large trees; 1999 – small seedlings to > 20cm, manually thinned 3 to 6m spacing, hardwoods eliminated except for ‘green breaks’. Random counts in green breaks 40-60 box trees/ha >100 years old++ 1886 thickly timbered with box and pine as well as ironbarks in the north-east. Massive reduction of eucalypts – early reference to box, pine and patches of ironbarks. Box trees >100 years old 40-60/ha + 500 pines / ha + many thousands of large pines>100 yrs old cut for milling by 1882.

Summary: forest of uneven aged box 40-60 trees/ha + dense sapling pine 400-800 stems/ha – size varying with site quality, smaller on poorer gravelly ridges. Ironbark in the NE + dense box dominated forest in SE. Density of shrubs related to density of tree stand.

Strahorn: Mitchell describes dense woods with White or Yellow Box. 1883 – 2 @ 20inch/acre + 4 @ 12inch/acre + 120 pine saplings <12 inch/acre; <12inch 40/acre + bigger stumps. Early post WWII ringbarking of eucalyptus/oaks that had survived earlier felling or grown since. Relief labour schemes through 60’s and 70’s – major programme of tree poisoning to eliminate hardwoods from areas where pine will grow. Most of what was destroyed was coppice growth from earlier ringbarking or felling - ‘They tell the story of having once been ringbarked to improve the grass and later being poisoned to improve the trees’ p79. Box becoming more dominant after no poisoning for the last 15 years in previously pine dominant areas. Drought thinned pines – greater mortality in unthinned than thinned areas; 6000 sleepers from ‘straight box’ (yellow box) + pines. Mature trees 10/acre of 150 years old. Natural thinning can produce a stand of different size classes though of much the same generation. Pre-settlement times density of box would have been as great or greater than 100 yrs ago & certainly far greater than it is today after concerted efforts at ringbarking and poisoning.

Summary: Mixed box of varying ages and well spaced maturing cypress pines with a predominance of the hardwood or cypress depending on site soil conditions + casuarina, grass, wattles, hopbush, budda.

Euglo: first settled 1851; fire through the area; 1915 young pine well thinned and all useless timber destroyed thick pine 120/acre, 90/acre 6-8 inch dbhob, 30/acre 8-11inch dbhob. Plot with grazing excluded totally – dense seedlings + grass reappearing; fire 1957 heavy loss
cypress, eucalypts & wattles re-emerged in dense stands – young cypress still rare in early 1970’s, 1980; >50 box trees/ha in early 19th century. Box stump counts up to 50/ha >180 years ago.

Summary: a forest of relatively open pine (60-80/ha) + box trees of much the same density in the north but fewer in the south and a grassy understorey with areas of Yarran and Rosewood in the west.

Pre-European forests - Cunningham – lots of various sizes and dimensions from seedlings generally growing in clumps to lofty trees of about 60ft. Phases differed between forests.

The explorers found a mosaic of vegetation across the central western region, and today's forests were part of that mosaic though not necessarily as we see them now … long term natural cycle influenced to a greater or lesser degree by Aboriginal burning. … To pick out any one date (1750) … ignores the fact that forests are and were dynamic systems, and fails to give a true picture of process’ (p131). ‘A cycle which may naturally take 300 years or more without major interference in being compressed into a third of that period, and at the same time, across almost the whole of the forests, one species has been deliberately promoted at the detriment of the others.’ (p132).

NB figures of natural cycles and changes through the last 200 years.


Abstract: Taken literally, the aim of biodiversity monitoring is to track changes in the biological integrity of ecosystems. Given the overwhelmingly dominant contribution of invertebrates to biodiversity, no biodiversity monitoring programme can be considered credible if invertebrates are not addressed effectively. Here we review the use of terrestrial invertebrates, with a particular focus on ants, as bioindicators in Australia in the context of monitoring biodiversity in Australia’s rangelands. Ant monitoring systems in Australia were initially developed for assessing restoration success following mining, and have since been applied to a wide range of other land-use situations, including grazing impacts in rangelands. The use of ants as bioindicators in Australia is supported by an extensive portfolio of studies of the responses of ant communities to disturbance, as well as by a global model of ant community dynamics based on functional groups in relation to environmental stress and disturbance. Available data from mining studies suggest that ants reflect changes in other invertebrate groups, but this remains largely undocumented in rangelands. The feasibility of using ants as indicators in land management remains a key issue, given the large numbers of taxonomically challenging specimens in samples, and a lack of invertebrate expertise within most land-management agencies. However, recent work has shown that major efficiencies can be achieved by simplifying the ant sorting process, and such efficiencies can actually enhance rather than compromise indicator performance.
Notes: Suggests that the overstocking of the country in the Cobar district in association with rabbits prevented the growth of grass to anything like its former extent and so caused the cessation of bush fires which had formerly occurred periodically allowing the 'noxious scrub' headway.

James Cotton - iguana prevalent and keeping rabbits down.

Tarella Stn - rabbits and drought have caused the disappearance of the edible bush - on some country there are thousands and thousands of dead mulga

T W Connolly (surveyor) a large part of the scrub has been permanently destroyed, particularly the mulga dense pine scrub

Henry Knight, Cobar: It is the scrub that is putting the carrying capacity back. Grass and scrub cannot be grown at the same time. In olden times, before the country was taken up it was subject to bush fires; but since the sheep have been on the country there have been no bush fires and that has allowed the scrub to increase

Paterson Ulonga Station: Good seasons: 1860-1863, 1867 exceptionally good, whole country was underwater; 1870 rained commenced in April and it rained almost continuously for 3 months, 1971-1873 good seasons; 1878-1881 (part) very good; 1886,1887; 1889,1890, 1891, part 1892 very good; 1892, 1893, 1894 (part); bad seasons: 1864-1866, 1868-1870 (part) very dry especially on the Lachlan; 1875-1877 very dry principally on the Murrumbidgee; Part 1881 & 1883, 1884 - record for 1884 one of the lowest; 1886, 1886 very dry on the Lachlan; 1888 very dry (lowest record); winter 1892 exceptionally dry; part 1894-1899 and part 1900 very bad seasons.

Abstract: Summary: First settled in the 1870s followed by much ringbarking and clearing. During this period 2 major invasions of scrub and timber regrowth have occurred. In the 1890s following a prolonged period of well above average rainfall much of the previous work was nullified by rapid increase in natural timber and shrub species. The 1901 Royal Commission considered this problem to be one of the major causes of depression in the Cobar area. Extensive scrub and timber regeneration caused a marked reduction in carrying capacity and was followed by a prolonged drought as well as a fall in commodity prices. The Royal Commission considered the absence of bushfires subsequent to occupation of the land to be the major reason for the increase in scrub and timber regrowth. Pointed put that prior to settlement regrowth was kept under control by occasional bushfires. An extensive bushfire in 1921 covering many thousands of sq miles (Louth to Nyngan) destroyed much of the regrowth that had appeared in the 1880s and 1890s. The second major regrowth occurred in
the 1950s as the result of another prolonged period of above average rainfall. This has also been followed by a prolonged drought period. Drought breaking rains in Jan 1968 with good follow up rains in May have brought little response to country with regrowth. Country assessed as 1 sheep to 10/15 acres in the late 1950s and early 1960s can now carry only 1 to 15/20 acres or less. Committee considers that the regrowth is not due to any particular factor but is a natural feature of the environment occurring as the result of a combination of factors and accentuated by the absence of natural fires.

Basic problem is one of declining productivity due to reduced grazing capacity and poor diet. Lack of ground cover causes high runoff which in turn leaves little moisture available for pasture growth; the resulting erosion causes more rapid runoff setting up a vicious cycle and a decline in grazing capacity. As competition from scrub increases pastures become sparser until normal levels of stocking lead to overstocking. Decline is rapid as surface soil becomes susceptible to water sheeting and there is less water for pasture growth. Runon areas from surrounding bare and eroded ridges are the most productive with good grass growth. Bimble box can thickly timber these flats. Rather than look for causes of timber and scrub regrowth we could regard it is natural and seek reasons why some country is relatively open. The extensive fires of 1921 burnt and killed a lot of scrub and timber and opened up an extensive area of country in the Cobar District. It may also have been responsible for the dense regeneration of scrub in some areas after the fires. Sheet erosion is of equal importance in deteriorating the productivity of the region.

Runoff from ridgy country can be harnessed by using spreader banks below relatively small catchments to increase herbage growth and reduce erosion. Contour furrowing has been shown to restore normal grazing capacity and encourage softer grasses to provide a reasonable diet for breeding ewes.

**Notes:** Types of Country: the difference between the 'hard red' country which comprises the problem area for scrub and timber regrowth and the remainder of the western division - Level country of the river-flood plains+ texture contrast soils, naturally treeless or very openly timbered, pastures highly nutritious; Belah-Rosewood and mallee scrub - thick in places but plenty of open areas, loose soil texture prevents degeneration by sheet erosion and water so that even in areas of thick scrub there are open areas; 'soft red' country - similar to 'hard red' - mostly fairly open and because of the loose nature of the soil is not seriously affected by sheet erosion by water and regeneration does not occur as readily; 'hard red' country - regeneration of scrub & timber takes place readily naturally, soils degenerated by erosion once they become relatively bare of ground cover

The Nature of the Problem: Evidence to the 1901 royal commission and to land board enquiries prior to 1890 suggested that land that had once been park like was then covered by thick scrub and timber. Record of scrub being cleared by bushfire in 1886. From the Royal Commission: Many reports of change from open poplar box country to thickening of cover by 'noxious scrub' and the occurrence of fires; James Cotton (stock inspector) "In the years 1880-1881 before the Cobar District was stocked and when it was being improved, the country was covered with a heavy growth of natural grasses - kangaroo grass, star grass, blue grass, mulga and other grasses. The western half of the district abounded with salt and cotton bush, together with the grasses mentioned. The ground was soft and spongy and very absorbent. One inch of rain then in spring or autumn produced a luxurious growth of fresh green grass.
The great difficulty seemed to be want of water. The country abounded also in edible shrubs and bushes and pine scrubs and other noxious scrubs were not noticeable. With the exception of a few gilgai holes, the district was absolutely waterless. There has been a gradual deterioration of the country caused by stock which has transformed the land from its original soft spongy, absorbent nature to a hard clayey smooth surface (more especially on the ridges) which instead of absorbing the rain, runs it off in a sheet as fast as it falls, carrying with it the surface mould, seeds of all kinds of plants, sheep manure, sand etc. to enrich the lower lying country and enrich it with pine, box and other noxious scrubs. The commissions report refers to the large amount of investment in clearing and ringbarking of timber and grubbing of scrub. In many cases the expenditure was nullified within a few years by regeneration of timber and scrub. In 1968 the scrub problem affects an area some 40-60 miles to the south, west and north of Cobar and approx 100 miles to the NE to the Bogan. In the affected areas the INS occurs in small patches 1-2 chns in area with small openings between patches. Little or no grass or herbage grows in the scrub patches and the intervening spaces are bare and suffering from sheeting by wind and water. Despite 3-6 inches of rain Jan 1968 and more in Apr & May, totalling 8-12 inches there has been virtually no response by pastures on INS country. Except for the runon flats, this country is no better grassed than during the 3 proceeding years of drought. Sheet erosion is complementary to the INS problem. It is considered that 3-6 inches of soils have been lost from 100s and 1000s of acres in the Cobar district and is an important factor in the decline in grazing capacity in the Cobar district.

_Causes of timber and scrub regrowth: An increase in density is a natural response to the above average rainfall between 1950 and 1956. The rainfall was more than double the average and the soil was wet for months. Much of the scrub regrowth can be traced to these years. 1962 was also a year with very high rainfall and much regeneration also occurred. The appearance of scrub did not make its presence felt until the ground forage which had grown tall in the years of high rainfall was reduced by grazing as dry conditions prevailed throughout 1957. As the grass and herbage was eaten out the seedlings and saplings became obvious. Factors suggested as causes: excessive grazing of ground forage and killing of edible trees and shrubs by ringbarking and grubbing of roots by rabbits - scrub infestations of the 1890s coincided with rabbit infestation - but Myxo removed this factor in early 1950s; intensive stocking in 1880s & 1898s + rabbits removed ground forage competition to unpalatable shrubs but not in the 1950s [but this was also grazed out and may have out competed the shrub seedlings given more time]. Regeneration requires a period of well above average rainfall followed by a couple of years of average rain when the seed prefers to germinate. Further above average rain wood keep the soil saturated for long enough to prevent competition from ground forage. Bushfires in 1921 and 1967 removed large areas of scrub. Provided that burning is done in the appropriate season with minimum environmental damage and subsequent grazing is deferred until growth is sufficient to withstand it, there is little if any damage. Remedial measures discussed.

Notes: Summary: This submission eliminates myxomatosis and over-grazing as causes and stresses the importance of runs of years of high rainfall and the lack of fire since European settlement, as the predominant joint cause. The effects of reduced fire incidence in semi-arid regions and its influences in promoting scrub invasion have been well documented - from the valuable commercial pine forest which is now the Pilliga Scrub, to the severely scrub infested Cobar-Byrock region (regarded by foresters as the new Pilliga because of the pine regeneration) and to the current invasion of the upper Darling by shrubs of low palatability. This produces declining carrying capacity, worsening management problems and increasing costs. Controlled use of fire offers the greatest prospect for prevention but it is too late to save much of the Upper West Darling but could play an important in allaying the problem is areas not yet seriously invaded and in the belah-Rosewood country in the Central-East Darling and lower West Darling. Scrub invasion will continue to be a problem of serious dimensions over a large part of the Western Division. It will continue to get worse unless landholders are prepared to accept fire as a management tool for scrub control and until Govt is prepared to provide staff to assist landholders to plan and supervise management burns as well as special measures to improve productivity.

History: Much of the mature and whipstick pine and stands of dense small box, the extensive stands of mulga and the moderate stands of wilga, yarran would have originated in the 1880s & 1890s. The huge fires (from Louth to the Bogan) of early 1922 following high rainfall in 1921 are assumed to have opened up the country considerably and cleaned up much of the hopbush, turpentine and punty bush which would have developed from the 1890s. Little survival of seedlings in the 1920s-1940s. Five years of excessive rainfall (1949, 1950, 1952, 1955, 1956) across the western division and in 1950, 1952 & 1956 the ground was wet throughout the winter. The following wave of scrub regeneration was confined largely to the level and very gently undulating hard red soils, generally west to a line due south of Louth with pockets occurring on hard red soils to the north of the darling east of the Warrego. The good rains of the 1963-4 season brought another cohort which thickened up existing stands and expand area as did the long run of excessive rainfall in the mid 1970s. In the far west the 1950s caused isolated pockets of scrub regeneration. There were already well established belts of hopbush and turpentine along the stock routes radiating northward and westward from Bourke, probably having developed initially in the 1890s as a consequence of the severe disturbance on the sander soils with the constant passage of travelling stock.

Causes of thickening: Overgrazing only has an indirect influence in keeping ground cover to a point where bushfires which normally followed a lush season and especially a pair of good seasons, were not able to establish. A frequent cause of invasion has been the removal of the larger trees by ringbarking or clearing replaced by shrubs. Clearing will bring forth a wealth of native shrubs and tree species.

Methods of control discussed including economics. This includes fire and ways of going about burning, clearing and cropping, clearing and water spreading, goats.

Discusses a plan for action. Of 32 million ha in the western Division 16 million ha have been affected or threatened by scrub invasion.

Archer S. R. (1989) Have southern Texas savannas been converted to woodlands in
Abstract: Introduction: Quantitative and historical assessments suggest that woody-plant abundance has increased substantially in arid and semi-arid grasslands over the last 50-300 years in many parts of the world, including Africa, India, Australia and South America. It has been widespread in North American grasslands as well. Descriptions of the physiognomic conversion of grassland to shrubland or woodland are abundant but little is known of mechanisms, rates or dynamics of this process. Simulations indicate that grasslands of the arid and semi-arid regions will become increasingly susceptible to woody-plant encroachment in response to anticipated global climatic changes.

The Rio Grande Plains of southern Texas and north-eastern Mexico offer some distinct examples of processes involved in the conversion of grasslands to woodlands. The natural vegetation has been classified as an *Acacia-Andropogon-Setaria* savanna. Present day vegetation is a subtropical thorny woodland. In many instances it is believed that these vegetation types have developed on areas of former grasslands. However the argument that the increased prominence of shrub lands and woodlands has contributed to the demise of the prairies and savannas in southern Texas is controversial.

Notes: Summary: At savanna sites in southern Texas discrete clusters of woody plants form in herbaceous clearings following the invasion of mesquite and arborescent legume. The growth rate of these clusters has been shown to vary with precipitation and size. A simulation model was developed to estimate rates of growth and development of these woody plant assemblages under different precipitation regimes on one soil type. In this simulation the establishment of other woody species beneath invading mesquite occurred within 10-15 years. As a cluster developed around the mesquite nucleus species richness increased rapidly for 35-45 years and became asymptotic at 10 species. Estimated age of the oldest Mesquite was 172-217 years but the model predicted that most clusters and mesquite plants were less than 100 years. There was no evidence of density dependant restrictions on recruitment or expansion so as new clusters were initiated and existing clusters expand, coalesce to continuous canopy, woodlands may eventually occur. Model output was also consistent with historical observations that the conversion of savannas to woodlands in the Rio Grande Plains has been recent and coincident with both heavy grazing by livestock and seasonal shifts in precipitation that began in the late 1800s. This is in agreement with woody-plant invasions documented in other North American arid and semi-arid systems by the direct aging of woody plants.


Abstract: Human induced changes in atmospheric chemistry and meteorology have the potential to impact a broad array of ecosystem processes over a range of the temporal and spatial scales. These may have direct and indirect effects that could influence management strategies and landscape responses to disturbances associated with natural events and land
use. The extent to which forecasted global changes are effective in altering local ecosystem properties will depend upon a variety of factors. In this paper, I address species life history traits and community landscape properties that can be used by land managers to anticipate local manifestations of global change.

**Notes:** Discusses the nature of change in vegetation, soils and ecosystem processes, focusing on species life history attributes.

Plant community and landscape attributes. Substantial variation occurs across landscapes and broad scale climatic variables cannot account for the spatial patterns shaping ecosystems on a local scale. As spatial and temporal frames of observation are diminished and resolution increased edaphic heterogeneity and disturbance (eg grazing, fire, cropping, flooding) assume greater importance in determining ecosystem structure and function. Our ability to anticipate future changes in vegetation hinges on our understanding of processes regulating community succession, stability and resilience. Stability: a measure of persistence in the face of disturbance - resistance (ability to avoid displacement with a given disturbance) & resilience (speed of recovery to former state after being displaced). These concepts presume disturbance and transition thresholds. If thresholds exist the magnitude of change a system can absorb before transitioning to an alternate state must be determined in the context of future environmental conditions. Schlesinger et al (1990) hypothesize that positive feedbacks are operational in desertification: scenario - long-term grazing of semi-arid grasslands by livestock produced spatial and temporal variation of soil resources (N & water), heterogeneity of soil resources then promotes establishment of shrubs which further localise soil resources under their canopies; as barren areas between shrubs develop soil fertility is reduced by erosion and gaseous emissions and a greater percentage of the soil surface become exposed. Soil surface and air temps increase & produce hotter, drier micro- and mesoclimate which favours drought tolerant shrubs over grasses. This positive feedback process is a potential mechanism for desertification in these regions, independent of climate. Positive feedbacks may also be initiated by species which redirect successional processes or disturbance regimes once established e.g. some woody plants (Sumac, honey mesquite, Acacias etc) may facilitate ingress and establishment of other woody species subsequent to their establishment in grasslands. This may be due to passive effects (e.g. perching sites) or active associated with alterations in soils and microclimate that favour the establishment of other plant species. Positive feedbacks are also initiated when species or growth forms alter disturbance regimes eg in western USA where introduced brome grasses have increased the fire frequency and are burnt in a self reinforcing fashion which ultimately leads to the conversion of perennial sagebrush-steppe to annual grassland.

Soil is the largest terrestrial pool of C, N & S and is intimately involved in the fluxes of these greenhouse elements


**Notes:** Quoted in Hudak 1999

**Abstract:** The size distributions of populations of four semi-arid perennial trees were investigated within Kinchega National Park in western NSW. For *Acacia ligulata*, *A. loderi* and *Alectryon oleifolius*, it appears that regeneration has been eliminated or at best severely limited at most sites. Some regeneration has occurred through recruitment of vegetative suckers in *Casuarina pauper*. Currently these vegetative recruits have high survival rates under both rabbit and kangaroo grazing, although such grazing frequently reduces the height of vegetative suckers back to ground level. Survival of seedlings of *Acacia ligulata* was very limited, with highest survival when mammals were excluded. There was no survival of seedlings of *Casuarina pauper* in the presence of rabbits and survival was poor when rabbits were excluded. Many seedlings of both species die through desiccation. The survival data from seedlings and vegetative suckers reinforce the patterns observed in the size distribution of populations. Within Kinchega National Park, control of rabbits is essential to initiate regeneration. A reduction in the total grazing pressure (especially rabbits, sheep, cattle and goats) is necessary in critical dry periods on semi-arid and arid grazing land if regeneration of perennials is to be encouraged.


**Abstract:** Main points of the summary: Aim of study - to investigate the difference in biodiversity and landscape function as a response to different levels of shrub cover within three regions in the Western Division of NSW. Little specific information available on the effects of woody shrub cover on biodiversity and landscape function in Australian or international rangelands. Woody weeds include *Eremophila mitchellii* (Budda), *E. sturtii* (turpentine), *Dodonaea viscosa angustissima* (Narrow-leaved hopbush), *D. v. spatulata* (Broad-leaved hopbush), *Senna artemisioides filifolia* (Punty Bush), *Senna artemisioides artemisioides* (Silver cassia). Effects of woody shrub cover on biodiversity and landscape function surveyed in open belah woodlands on sandplains north of Ivanhoe, rolling sandplains between Wanaaring and Louth, hard red country west of Cobar. 37 sites evenly distributed across these three regions.

**Results** - In total 140 vertebrate species, 30 invertebrate orders, 94 ant taxa recorded. Each region contained some distinctive taxa within each broad taxonomic group and also shared
taxa. Individual taxa, guilds and taxon associations varied in their responses to woody shrub cover or density. This included: increasing abundance, decreasing abundance, preference for intermediate shrub cover, avoidance of intermediate shrub cover, preference for one cover extreme, avoidance of one cover extreme, generalists. In the Ivanhoe region 5.4% of taxa were increasers or decreasers, 4.1% preferred or avoided a particular cover type; Wanaaring-Louth region - 15.4% & 3.3%; Cobar region - 19.3% & 5.4%. More taxa increased than decreased. Reasons for these taxa remain difficult to interpret due to limited ecological data. Landscape function was generally better and more variable in the Cobar region. Landscape function was markedly poorer in the Wanaaring-Louth region with sites tending to be 'leaky' in terms of both soil and water. Where woody shrub patches functioned as resource sinks, soil condition was consistently better in terms of soil stability, infiltration capacity and nutrient cycling status than in adjacent run-off areas. Soil surface conditions tended to be slightly better in nearby treed and perennial grassland resource sink patches. Where shrubby patches functioned as a resource-source zone, they tended to be of equivalent landscape function to source patches with a moderate vegetation cover and were always better than the bare source patches.

Principal Conclusions: 'woody weeds have biodiversity value with many taxa using shrub encroached habitat; most taxa do not respond significantly to woody shrub cover or density; shrub cover has a neutral or positive effect on landscape function in areas where the perennial ground cover has been degraded but are not as effective as extensive dense perennial grasslands or stands of trees with associated debris. Management and research directions: biodiversity and landscape function values of shrub patches of differing densities and scales must be part of the landscape management decisions; the establishment and maintenance of a mosaic of woody shrub densities within the mix of broader vegetation, soil and landform types should best achieve balance; management goals need to be established at local and regional scales, utilising site-specific information from on-ground inspections; use local knowledge; maintain landscape function status with retention of resources in the local area regardless of the management strategy being used; manage and maintain ongoing shrub encroachment.

Notes: Fauna & Flora: Increaser species with increased shrub density include spiny-cheeked honeyeater, small insectivorous birds, tree and shrub canopy-feeding birds (bark), burrowing reptiles, some ant taxa. At a landscape scale, excluding the influence of other factors (e.g. water, nutrients) greatest richness would be expected in areas with maximum environmental complexity. Palatable plant taxa were not necessarily detrimentally affected by high woody shrub cover. Landscape function: woody shrub cover had a neutral or positive effect on landscape function; woody shrub and treed resource source patches had soil surface condition comparable to other source patch types.

Notes: Survey was taken in response to concern over erosion and management in large areas being invaded by inedible shrub species in the west Darling region. Survey found that sandplains, dunefields and any alluvial plains, which together account for half of the survey region are potentially susceptible to shrub invasion, mostly at high densities. This could decrease grazing capacity by 30%. Most areas without sandy soils will support only slight to moderate densities.


Abstract: Piñons and junipers, that dominate many semi-arid landscapes in the western United States, have invaded some sagebrush and grassland areas and possibly increased in density since Euro-American settlement. Exclusion of fire by livestock grazing and intentional suppression is thought to have been a cause of these changes. National assessments suggest that many woodlands have missed one or more low-severity surface fires and are thus in poor condition, requiring restoration. We undertook a systematic review of seven questions about fire history, fire severity, and the role of fire in these woodlands to evaluate the scientific basis for the national assessment. First, unless piñons and junipers record fire by means of fire scars, it will be difficult to reconstruct fire history. Evidence suggests that most species of piñons and junipers can record fire by means of scars, but scars may be uncommon or absent in some cases and common in others. This variability in scarring has competing explanations that are poorly substantiated. Second, evidence exists for at least three modes of low-severity surface fires in these woodlands: (1) spreading surface fires, (2) patchy surface fires of small extent, and (3) an absence or near absence of surface fires. Methodological problems limit our ability to assess how common each mode is, but spreading, low-severity surface fires were likely not common. Third, there are no reliable estimates of mean fire intervals for low-severity surface fires in these woodlands because of methodological problems. Fourth, fires can kill small trees in true savannas and grasslands, helping to maintain a low tree density, but in most piñon–juniper woodlands low-severity surface fires do not consistently lower tree density and may become high-severity fires. Fifth, nearly all observed fires since Euro-American settlement in these woodlands were high-severity fires. In only two studies is there sufficient information to allow a conclusion about whether high-severity fires have or have not increased since settlement, and in these cases the authors conclude they have not. Sixth, the fire rotation for high-severity fires is estimated in only two studies, 400 years in one case, 480 years in the other. Finally, fires may in some cases burn with mixed severity. In conclusion, national fire plans and assessments of the condition and health of piñon–juniper woodlands in the western United States are based on premature and likely incorrect conclusions about the natural fire regime in piñon–juniper woodlands. Local research is essential, at the present time, if effective, scientifically based restoration prescriptions are to be derived.

Notes: Causes thought to be fire exclusion, livestock grazing & climatic fluctuations but which
factor is the most important? This is a very systematic review of the literature addressing the question of the impact of fire. Previous occurrence of low-severity fires difficult to determine because of the infrequent recent fires. Restoration of fire in these woodlands needs to be based on sound science. Until this is possible suggest a more cautious research-based local restoration strategy.


**Notes:** Proceedings of an ANZAAS conference held in 1980


**Abstract:** Umberumbra is the aboriginal name for two waterholes in the floodout of the Crooked Holes Creek. Intense stocking destroyed the floodplain by reducing pasture cover on the catchment and floodplain and increasing the flow of water through the floodplain. Gullies up to 2m deep eroding through the floodplain meant that water was no longer able to spread over the floodplain and most of the area died as it became progressively starved of water. Reclamation included light stocking, spelling and fencing as well as construction using earthworks to divert water out of gullies and allow it to spread in a shallow, slow flowing sheet over intact parts of the old floodplain. Woody weed encroachment has occurred over much of the old floodplain. There has been one successful fire on the area first reclaimed with earthworks 7 years before and hopes to get in some more burns. Before reclamation works there were 3 grass species + a few ephemerals after rain; at the time of writing, there were at least 22 species. Weight of bullocks turned off this area had increased dramatically due mainly to better nutrition.


**Abstract:** Broad-scale fire eliminates malleefowl in the short term and even 20-30 years after fire, breeding densities were found to be only a third of those in long-unburnt habitats. As a consequence, optimal fire-frequency for malleefowl conservation is likely to be in excess of 60 years. The negative effects of fire are mitigated if fires burn patchily. In Wyperfeld National Park, some Malleefowl were able to survive and reproduce in burnt areas where relatively small areas of unburnt vegetation remained as core-refuges. It is argued that the primary role of fire in the management of malleefowl is to lower the chance of fire in habitats important for malleefowl, and to encourage the formation of islands occurring in the event of wildfire.
Notes: Mallee habitat is both fire-dependent and fire promoting and fire plays a vital role in determining floristic and structural diversity. The pattern of a fire (size and patchiness) is critically important for animals as unburnt patches may provide refuges after fire and burnt/unburnt boundaries may provide other benefits.


Abstract: A vegetation classification titled, NSW Vegetation Classification and Assessment (NSW VCA), is described. It aims to classify the native vegetation of NSW covering 80 million hectares distributed across 18 Australian Bioregions. It is estimated that between 800 and 1200 plant communities will be described. The best available data is used to establish the classification including vegetation map descriptions, floristic groups derived from plot data and expert advice. Extensive field checking assists with the classification and status assessments. Plant communities are listed under five hierarchical levels and are recorded on a database containing 90 fields supported by 45 tables and 64 forms. 39 database reports list plant communities for several types of planning regions and under state and broad vegetation classifications. Database fields include plant community scientific name, common name, three layers of characteristic species, an 'Authority field that cites references supporting the definition of the community, substrate, soils, landform, distribution by various regions including bioregions and CMA areas, descriptions and lists of threatening processes and aspects of condition. Estimates of pre-European extent, current extent and areas in public reserves and secure property agreements are recorded and qualified with accuracy levels. One of five threat categories: 'critically endangered', 'endangered', 'vulnerable', 'near threatened', or 'least concern' is assigned to each plant community based on the application of six criteria including: the proportion of remaining extent compared to an estimated pre-European extent, loss of key species, and plant community integrity.


Abstract: For the western plains of NSW 213 plant communities are classified and described and their protected area and threat status assessed. The communities are listed on the NSW Vegetation Classification and Assessment database (NSWVCA). The full description of the communities is placed on an accompanying CD together with a read only version of the NSWVCA database. The NSW western plains are 45.5 million ha in size and covers 75% of NSW. The vegetation descriptions are based on over 250 published and unpublished vegetation surveys and maps produced over the last 50 years (listed in bibliography), rapid field checks and the expert knowledge on the vegetation. The 213 communities occur over eight Australian bioregions
and eight NSW CMA areas. As of December 2005, 3.7% of the western plains was protected in 83 protected areas comprising 62 public conservation reserves and 21 secure property agreements. Only one of the eight bioregions has greater than 10% of its area represented in protected areas. 31 or 15% of the communities are not recorded from protected areas. 136 or 64% have less than 5% of their pre-European extent in protected areas. Only 52 or 24% of the communities have greater than 10% of their original extent protected, thus meeting international guidelines for representation in protected areas. 71 or 33% of the plant communities are threatened, that is, judged as being 'critically endangered', 'endangered' or 'vulnerable'.

While 80 communities are recorded as of 'least concern' most of these are degraded by lack of regeneration of key species due to grazing pressure and loss of top soil and some may be reassessed as being threatened in the future. Threatening processes include vegetation clearing on higher nutrient soils in wetter regions, altered hydrological regimes due to draw-off of water from river systems and aquifers, high continuous grazing pressure by domestic stock, feral goats and rabbits, and in some places native herbivores - preventing regeneration of key plant species, exotic weed invasion along rivers and in fragmented vegetation, increased salinity, and over the long term, climate change.

To address these threats, more public reserves and secure property agreements are required, vegetation clearing should cease, re-vegetation is required to increase habitat corridors and improve the condition of native vegetation, environmental flows to regulated river systems are required to protect inland wetlands, over-grazing by domestic stock should be avoided and goat and rabbit numbers should be controlled and reduced. Conservation action should concentrate on protecting plant communities that are threatened or poorly represented in protected areas.


Abstract: Based on a selection of quotes from early European explorers and settlers, and modern authors including Flannery (1994), Ryan et al. (1995) suggest that, at the time of European settlement of eastern Australia: the vegetation was mainly composed of grassland and grassy woodland; Aborigines burnt most of the country every year or so; and a lack of fire after European settlement led to thick regrowth that was subsequently ringbarked and cleared by settlers for agricultural expansion. Ryan et al. (1995) present one line of evidence in trying to explain pre-European vegetation and overlook the extensive scientific literature on past and present vegetation, and on fire ecology in Australia. By referring to the scientific literature, and by re-examining the same historical sources used in Ryan et al. (1995), we examine the views of Ryan et al. (1995) and also question hypotheses put forward in The Future Eaters by Tim Flannery (1994) and the views about pre-European tree density in A Million Wild Acres by Eric Rolls (1981).

The quotes used in Ryan et al. (1995) mainly cover parts of south-eastern Australia between
Tasmania and Brisbane, but do not deal with particular regions in a systematic way. They generally refer to one type of vegetation formation - grassy woodland, which mainly occurs on clayey soils in drier coastal valleys, on non-siliceous soils in the undulating tablelands and on the western slopes. The explorers may have favoured travelling through these areas because they occur near rivers (water), had an open understorey and because some explorers were employed to seek out suitable grazing lands. Using three historical estimates of tree density in grassy woodlands, we estimate there was an average of 30 large trees per ha spaced about one tree width apart. This contrasts with Rolls' estimate of 4 large trees per ha and the perceptions of Ryan et al. (1995) about the structure of a woodland. We found frequent references in the explorers' journals to vegetation containing a dense understorey including coastal heath, shrublands, rainforest and dense eucalypt forests. We found no evidence that most of south-east Australia's vegetation was annually burnt by Aboriginal people and provide examples where explorers' notes about fire have been misinterpreted or inappropriately extrapolated by Ryan et al. (1995) and Flannery (1994).


Abstract: Savannas form a large fraction of the total tropical vegetation and are extremely fire prone. We measured radiative, energy and carbon exchanges over unburned and burned (both before and after low and moderate intensity fires) open forest savanna at Howard Springs, Darwin, Australia. Fire affected the radiative balance immediately following fire through the consumption of the grass-dominated understorey and blackening of the surface. Albedo was halved following fire of both intensities (from 0.12 to 0.07 and from 0.11 to 0.06 for the moderate and low intensity sites, respectively), but the recovery of albedo was dependent on the initial fire intensity. The low intensity fire caused little canopy damage with little impact on the surface energy balance and only a slight increase in Bowen ratio. However the moderate fire resulted in a comprehensive canopy scorch and almost complete leaf drop in the weeks following fire. The shutdown of most leaves within the canopy reduced transpiration and altered energy partitioning. Leaf death and shedding also resulted in a cessation of ecosystem carbon uptake and the savanna turned from a sink to a source of carbon to the atmosphere because of the continued ecosystem respiration. Post-fire, the Bowen ratio increased greatly due to large increases in sensible heat fluxes. These changes in surface energy exchange following fire, when applied at the landscape scale, may have impacts on climate through local changes in circulation patterns and changes in regional heating, precipitation and monsoon circulation.

Abstract: Pollen and macroscopic charcoal have been analysed from a sedimentary sequence representing approximately 6100 years from a site within Wollemi National Park. This is located to the north-west of Sydney and forms a part of the Greater blue Mountains World Heritage Area. The aim of the work was to examine the prehistoric interrelationships between vegetation, fire and human activity. There were relatively minor changes in the vegetation over the last approx 6000 years, perhaps reflecting the climate- and fire-resilient nature of the sclerophyllous vegetation found on Hawkesbury sandstone throughout the Sydney Basin. Casuarinaceae declined in the late Holocene, a trend that has been detected in numerous paleoecological studies throughout south-eastern Australia. This decline was unrelated to fire, which has been a persistent feature at the site over the entire analysed sequence. The fire regime at the site changed from 5.7 ka, which is interpreted as reflecting the onset of increased climatic variability associated with El Nino-Southern Oscillation (ENSO) events. Another dramatic change in the fire regime occurred at 3 ka, which was coeval with archaeological changes in the region. It is possible that the change in fire activity from 3 ka represented an alteration to Aboriginal management strategies associated with an increasing population and/or the increased risk of conflagrations in an ENSO-dominated climate.

Notes: Fire history of the Sydney basin is unclear - Aboriginal use of fire included for hunting and other purposes but ecological effects on the vegetation are uncertain. Martin (1994) suggests that human occupation over the past 5000 years at the Kurnell Peninsula had little impact on the vegetation through fire use but cautions that the concept that Aboriginal people were 'careful custodians of the land' may have to be re-evaluated and suggests that low population numbers were more relevant than care. Fire was a persistent feature of the past 6000 years but there was a decline in fire at Kurringai Chase National Park attributed to the removal of Aboriginal people with the arrival of European people. The abundance of marine resources may have reduced the need for fire in managing vegetation on the coastal areas. The ecological importance of appropriate fire regimes to Sydney sandstone communities is well documented and there has been concern that the recent high fire frequency will affect long term biodiversity of Wollemi National Park. The results of this study generally support the conclusion of several authors that the vegetation in south-eastern Australia has not changed greatly in the last 6100 years. During the late Holocene forest canopies opened up due to climatic change or the intensification of human activity - attributing a cause is difficult - factors include hydrological evolution and ecological succession. Suggest that Aborigines may have begun intensively managing fire during the late Holocene to reduce fuel loads in response to the risks associated with living in a fire prone environment under an ENSO dominated climate - possible a lower intensity higher frequency fire regime. No apparent relationship between overall vegetation changes & fire activity in the pollen curves bur some broad relationships: Dodonaea (hopbush spp) often become more abundant during periods of high fire activity - evident at Wollemi site with higher concentration of hopbush pollen 5700-3000 years ago when charcoal accumulation was high. Suggests that in this setting hopbush is a good indicator of disturbance associated with intense fire activity.

There have only been slight changes to the composition of the mixed Casuarina-Eucalypt woodland with a shrubby sclerophyll understorey which currently surrounds the swamp in
Wollemi - others have suggested that most of the characteristic vegetation in SE Aust were established by 6000 years ago and the resilience of the Sydney flora may mean that it is relatively resistant to to minor climatic changes. Macroscopic charcoal abundance increased abruptly at 5700 years ago at Kings Waterhole Swamps likely to be associated with the onset of the ENSO dominated climate when more intense natural fires became a feature of the landscape. At 3000 years there was a major decrease in charcoal abundance suggesting altered Aboriginal activity in the region. It is likely that from 3000 years low-intensity anthropogenic fires were a feature of the landscape.


**Abstract:** Two small colonies of the rare western hare-wallaby exist within the Tanami Desert Sanctuary, adjacent to the stock route. A careful search of over 2300 sq km of similar habitat failed to reveal further colonies. The colony areas are characterised by a distinct fire patterning. Cool, winter fires deliberately lit along the stock routes and roads have resulted in a tight mosaic of different vegetative regenerative stages. Other areas are regularly subjected to extensive, hot, summer fires started by lightning. It is considered that only the winter fire pattern produces conditions suitable to the animals’ requirements for cover and food. The use of fire by nomadic aborigines would have resulted in large areas suitable for the hare-wallaby. Numbers of the species are known to have declined at the time when the desert people were beginning to congregate in missions and settlements.

**Notes:** The Mala was locally abundant through much of its range although subject to decline during drought. Land units in the desert saline country has distinct survival valued for the species - the variety of land units ensures a diversity of feeding opportunities for all seasons and including foods such as regenerating forbs after fire. In the absence of deliberate aboriginal burning, the western desert country has been subjected to uncontrolled hot summer fires that have destroyed the hare-wallaby’s habitat over most of its range.


**Notes:** Landowner from NW of Broken Hill - between the Barrier Ranges and the SA/NSW border. First well sunk in the area well before Broken Hill ore discovered in 1883 - 7000 sheep watered there year in year out for many years. Devastation still evident on this open soft country. An earthen tank (dam) filled with drift sand, stone hut and stockyard almost completely buried. Letter written to owners by manager in 1880s that he had sufficiently improved the land to carry 40000 sheep - the same country in the past 50 years has carried 12-14,000 sheep, plus working stock - eg 200 horses, + camel & donkey teams. Rabbits - 1920s (?) as a boy 1200 rabbits captured/night. Late 1940’s early 50s, Kidman interests resumed and cut into smaller holdings each with separate homesteads etc - suggests no sheep remained the
same but were more spread out. Myxo also introduced 1950 and rainfall improved with longer time between droughts. Large areas previously subject to regularly drifting sand and severe dust storms slowly consolidated and were covered with grasses and herbage and the drift and dust disappeared. Perennial bushes regenerated, young mulga seedlings appeared and grew into mature trees and in some cases very dense thickets of mature trees of considerable proportions.

Overstocking: Running too many stock for a given area to sustain over an extended period - number varies with the country - overall control by rainfall.


**Abstract:** Changes in ecological concepts and a new focus on biodiversity as a central objective have led to changes in fire policies in South African savanna parks. Prescribed burning using fixed fire intervals is being replaced by systems that promote more variable fire regimes and greater management flexibility. Three policy alternatives have been proposed for Kruger National Park: a lightning fire policy, patch mosaic burning, and burning based on ecological criteria. There is no agreement as yet on which policy to adopt. However there is growing consensus on the use of a management system using 'thresholds of potential concern' to evaluate the outcome of different policies. These thresholds have been established for numerous indicators, help focus monitoring activities, and guide managers on the need for active intervention. We discuss the applicability of the policy alternatives for preventing successional change from savanna to forest and promoting grazing lawns and their associated grazers. We conclude that none of the current policies is universally applicable. A prescriptive program of frequent, high intensity burns will be required in mesic savannas to prevent succession to forests. In arid savannas, fire regimes designed to promote variable fire frequencies and fire sizes would be preferred to maintain greater diversity of grassland swards and grazer communities. The lessons learned from fire policy debates in South African savannas are of wider relevance for managing conservation areas elsewhere.


**Abstract:** It is difficult to find references to fire in general textbooks on ecology, conservation biology or biogeography, in spite of the fact that large parts of the world burn on a regular basis, and that there is a considerable literature on the ecology of fire and its use for managing ecosystems. Fire has been burning ecosystems for hundreds of millions of years, helping to shape global biome distribution and to maintain the structure and function of fire-prone communities. Fire is also a significant evolutionary force, and is one of the first tools that humans used to re-shape their world. Here, we review the recent literature, drawing parallels between fire and herbivores as alternative consumers of vegetation. We point to the common questions, and some surprisingly different answers, that emerge from viewing fire as
a globally significant consumer that is analogous to herbivory.


**Abstract:**
**Notes:** Factors affecting woody weed encroachment: direct or indirect effects of activities of European settlers - changed fire practices and grazing are major causes. Altered soil moisture dynamics is also a suggested cause of encroachment. Seasonal conditions are important in controlling establishment. Generally encroachment follows periods of well above average rainfall.

**Climate:** Climatically induced changes in the West Darling region of NSW appear greater than changes due to overstocking. Climatically induced changes affect different species over different time periods - important to understand natural veg changes and cycles.

**Soils:** Influence incidence and nature of shrub encroachment. Lighter soils with shallow topsoil first affected - these have low water holding capacity giving deeply rooted woody species an advantage over shallow rooted grasses. Microtopography affects shrub seedling survival and determines species distribution. Soil disturbance by mechanical clearing appears to increase the number of woody shrub germination and seedling survival.

**Grazing:** Increases in woody shrub are commonly attributed to overgrazing but grazing may not have a direct role. Other factors may include changes in soil moisture conditions, perennial grass competition, changed ability of land to carry fire etc.

**Competition:** For moisture and light - prime factor in restricting the invasion of shrubs into semi-arid grasslands. Infrequent periods of exceptionally high rainfall may reduce moisture competition enabling seedlings to establish in dense stands e.g. in 1974 when herbage biomass was up to 6t per ha. Burrows considered that while grasses have an initial advantage during establishment on infertile soils because of fast growth rates and phosphorus absorption, woody species develop a more extensive root system which eventually improves their drought survival and ability to absorb nutrients - woody species are more capable of utilising low levels of soil nutrients. This dynamic is also influenced by selective grazing.

**Fire:** Fires tend to occur only following years of exceptional rainfall and is possible within 2 years of such rainfall events.

**Ecological Principles and implications for managing woody weeds.** 12 points highlighted including: The best and cheapest ways of woody weed control is before they form dense mature stands - pastures are maintained, management difficulties are avoided and spoil erosion from bare ground which aids woody weed establishment is avoided; management and control strategies which maintain maximum grass cover and minimise soil surface disturbance and soil erosion will reduce number and survival of seedlings, under drier conditions perennial grasses will reduce seedlings. The problems of managing woody weeds in semi-arid grazing lands are complex. Removal of woody shrubs without consideration of the species that will replace them could further decrease ecosystem sustainability.

**Control:** Fire: The ability of woody weeds to survive fire differs greatly between species. If fire used managerial problems will occur e.g. decision re whether to destroy available feed,
destocking of areas and risk of soil erosion if recovery delayed. Variables which need to be considered before the implementation of prescribed burning are fire behaviour, public risk, operational costs v's alternatives, potential for wildfire, environmental & social impacts. To be successful the strategy requires an ecological understanding of the process.


Abstract: Germination and survival of seedlings of four woody weed species (narrow-leaved hopbush Dodonaea attenuata, turpentine Eremophila sturtii, punty bush Cassia eremophila var. eremophila and silver cassia C. artemisioides) were examined, together with their phenology, at four sites which differed in shrub density, grazing pressure and topography in the Bourke - Wanaaring region of western New South Wales over the period 1979 to 1982. Although emergence varied between species (D. attenuata: 5,000-30,000 seedlings/ha; E. sturtii: 3,000-10,000 seedlings/ha; Cassia spp.: 2,000-4,000 seedlings/ha), the conditions favourable to large scale establishment depended mainly on rainfall during late autumn and winter for germination and that of the summer following germination for survival of all species. Turpentine required larger rainfall events or prior rainfall events for seedling germination. Soil disturbance enhanced seedling emergence, growth and survival of D. attenuata, by increasing soil moisture content deep in the profile. Sandhill areas showed significantly higher emergence levels for D. attenuata. The higher emergence of seedlings on densely shrubbed areas was most probably due to higher soil seed loads. Micro-depressions and sandplains favoured survival of all species. Grazing, mainly by rabbits, had no specific impact on emergence of any of the species, but reduced the survivorship of D. attenuata. Predation by insects had a negligible effect. Hopbush flowered in all years between July and October and turpentine flowered from May to September. Those that flowered were prolific. Seed loads had been dropped by late November. Generally, hopbush shrubs had attained 2 m before flowering but in one year 86% of those above 1 m high flowered. Turpentine generally flowered after it had attained 50 cm, although in one year one plant flowered when less than 25 cm. Encroaching populations of shrubs should be controlled before they mature and form dense stands. Hopbush and turpentine control programs should be completed before the end of winter, just before annual seed set. Control of young establishing stands of hopbush should be undertaken before they reach a height of one metre and 50 cm for turpentine. Rapid expansion outside treated areas is unlikely, however, occasional 'outlier' shrubs should be controlled before they mature and produce seed.

Notes: The phenological studies of the four woody shrubs 'suggest that to be most effective, hopbush and turpentine control programmes should be completed before the end of winter, just before annual seed set. As these shrubs are such prolific seed producers, it is important that land managers reduce encroaching populations of shrubs before they mature and form dense stands. Strategy in timing of operations will effectively prevent an increase in levels of seed in the soil. Control of young establishing stands of hopbush should be undertaken
before they reach a height of one metre and for young turpentine, 50cm. This agrees with Hodgkinson & Griffin (1982). Wider observation indicate that over recent years these heights were reached over 5-7 years. Once mature shrubs are controlled, rapid expansion outside treated areas is unlikely, with only occasional individuals establishing at a distance. But these outlier shrubs also need to be controlled.


Abstract: Growth and survival of hopbush (Dodonaea attenuata), turpentine (Eremophila sturtii) and punty bushes (Cassia eremophila and C. artemisioides) were studied in relation to the effects of grazing and shrub density, at four sites in the Bourke-Wanaaring region of western New South Wales during 1979 to 1982. Hopbush shrubs grew faster than turpentine and punty bushes. Small hopbush grew better on open areas, while mature shrubs grew better in dense stands. Turpentine showed better performance in open areas, and punty bush growth was unaffected by shrub population density. All these species showed a high survival rate, particularly in height classes greater than 25 cm, and they kept growing even during drought periods. The effects of grazing on survival were inconclusive. Hopbush and turpentine root development was rapid, attaining depths of over 1.1 m in wet soils, 14 weeks after germination. Mature plants in the field, both hopbush and turpentine, were observed to have extensive lateral root networks at either 22 cm or 30-70 cm soil depth respectively, as well as a tap root system. The characteristics of both species help explain the competitive advantage of these shrubs over herbaceous species, and their survival capability in times of drought. Competition of hopbush with the perennial grass woollybutt (Eragrostis eriopoda) and annual herbage was also examined. In spring, survival of hopbush seedlings was favoured within woollybutt tussocks, this situation being reversed in autumn. Woollybutt biomass was negatively affected by the proximity of hopbush shrubs. Annual herbage seemed not to have any effect on hopbush survival, although shrub seedlings grew better under conditions of moderate herbage cover. Microtopography affected the establishment of both grasses and shrubs, with depressions favouring the growth of grasses at the expense of shrubs during periods of adequate moisture, and the growth of shrubs during drier times. The findings suggest that the woody weed problem is unlikely to wax and wane and that turpentine may be particularly difficult to control. Maintenance of high levels of pasture cover from perennial grasses and annuals may slow down recruitment and growth in open areas with scattered parent shrubs, where control will be less costly, and may contain future spread.

Notes: Study in the Bourke-Wanaaring region. Concluded that control programmes should concentrate on seedlings but wait for summer mortality before undertaking controls.

Abstract: This paper discusses the impact of landscape burning on the Australian biota and the ecological consequences of the cessation of this practice. Despite many confident assertions it is surprising how little is known about Aboriginal fire usage in the near or more distant past and virtually nothing is known about the fire usage of the first colonists 50,000 years ago. Studies of the ecology of *Callitris intratropica* have provided some important insights into the ecological effect of Aboriginal landscape burning in northern Australia.

Notes: Good species to use as indicator as it is long lived (250 years) and most mature trees have crossed the transition from traditional to post-traditional landscape practices, it occurs in small patches within a Eucalyptus savanna matrix. Although it tolerates infertile soils and water stress, its fragmented distribution is puzzling but can be explained by its sensitivity to fire, especially the seedlings which cannot withstand low intensity fires. Absence of fire allows for very dense stocking with limited density dependant mortality. These termite resistant trees are also a valuable indicator of landscape change because they remain in the landscape after they have died. This allows ecologists to detect distribution changes and is also seen by traditional owners as an indication that the country was not being properly managed. Traditional Aboriginal fire regimes are thought to have been characterised by numerous low intensity fires while large scale high intensity fires are more typical of European land management. This species is a powerful bio-indicator of landscape change in the monsoon tropics following the cessation of Aboriginal burning but the fate of individual populations also requires consideration of local factors such as the presence of micro-topographic safe sites for seedling establishment and the nature of surrounding vegetation. Given the rapid loss of cultural knowledge from so many Australian landscapes we can never know the details of how and why the country was burnt.


Notes: Powerpoint presentation providing illustration of fire regimes across Australia, a biogeography of fire, illustrates the recurrence of major fires across the landscape and assesses the consequences of global change in the major vegetation zones including the rangelands. Also models the potential for climate driven change in these major zones with a case study of Sydney and the Blue Mountains.

Abstract: The link between ‘fire mosaics’ and persistence of animal species is part of a prominent ecological/land management paradigm. This paradigm deals largely with the effects of fire on animals on the basis of individual events. The universality of the paradigm can be questioned on a variety of grounds, a major deficiency being the inability to deal with quantitative effects of recurrent fire (the fire regime). A conceptual model of fire-related habitat elements is proposed for exploration of a continuum of species/habitat/landscape/fire regime combinations. This approach predicts that the dependence of species on fire-mediated habitat heterogeneity will be highly variable and strongly context-dependent. A spatially explicit simulation model was used to examine the persistence of malleefowl (*Leipoa ocellata*) in a specific landscape/habitat context where dependence on fire-mosaics should be high. Results suggest that persistence of *L. ocellata* populations will be dependent on intervention using small patchy fires but that there is an optimum rate of intervention. Results were sensitive to spatial pattern of prescribed fire, landscape type (topography) and probability of wildfire. Underlying effects of the fire-interval distribution (the ‘invisible’ mosaic) on plant species and habitat account for these results. A management emphasis on species/landscape context and awareness of the ‘invisible’ mosaic is advocated.


Abstract: The mallee shrublands of semi-arid, southern Australia are significant for their biodiversity. Mallee (dominated by *Eucalyptus* spp. with a multi stemmed habit) inhabits dunefields, sandplains and flats. Soils affect the density of the overstorey and understorey composition, which in turn affects flammability. Coarse-scale fire patterns and fire regimes are probably influenced by the mix of community types. Fire behaviour is governed by the discontinuous nature of fuels with cover of eucalypt litter often insufficient to sustain spreading fires. Perennial hummock grasses (e.g. *Triodia scariosa*) or ephemerals provide fuel continuity in some cases. Thus mallee exhibits regular and stochastic patterns of fuel accumulation and flammability. Fire sizes of up to c.100,000 ha can result from ignitions by lightning and severe weather associated with summer storms and current fire regimes are dominated by such fires on a decadal basis. A variety of functional groupings of plants occurs within mallee with distinct fire regime requirements, ranging from dominant obligate seeder *Callitris* spp and resprouting *Eucalyptus* spp to ephemeral herbs and grasses. Differing fire regimes will affect floristic composition and structure. Patterns of animal responses to fires (e.g. reptiles and birds) are affected by the plant community floristics and structure. Notable are endangered birds (e.g. the malleefowl *Leipoa ocellata*) that are most abundant in long unburnt mallee. Quantitative studies of fire regimes are required to resolve management dilemmas posed by the necessity to conserve a range of biota with disparate fire regime requirements. The fragmented nature of mallee vegetation requires particular consideration.
Notes: With highly discontinuous fuels as found in mallee, a multi faceted approach to the problem of predicting fire spread is needed.

Flame size is dependant on height and diameter of individual spinifex hummocks and the size and spacing of hummocks is important for fire propagation. In communities without triodia, flammability is a property of ephemeral herbs, forbs and other grasses. Stochastic variation in cover & biomass of ephemerals are governed by rainfall and the flush of ephemerals is most pronounced 3 years after fire. In addition biomass might be tightly related to cumulative rainfall effects. However the switch from non-flammable to flammable state in mallee is a function of drought followed by high rainfall. Mallee fire weather is predominantly determined by hot dry summers.

Size and timing of mallee fires appear to be linked: on average ignitions from lightning are unlikely to produce substantial fires due to fuel discontinuity across the landscape and the periodic occurrence of large mallee fires results from above-average antecedent rainfall. This rainfall will promote prolific herbage growth in areas with heavier textured soils and result in high levels of fuel continuity and fine and coarse spatial scales. Lightning fires will then be large if accompanied by strong winds.

Mallee fire size and regime: Dominated by very large fires on a decadal scale with few or no intervening fires. Prescribed burning may need to be conducted in more extreme weather conditions (late spring / early summer) than that recommended for forests in order to produce effective burns of a reasonable size.

Plants responses: In recently burnt mallee species richness is higher than in long-unburnt mallee due to the occurrence of fire induced ephemerals.

Fauna responses: For reptiles the importance of triodia is in providing micro-climatic refuge from temp and humidity extremes. Unlike spinifex grasslands some studies have found lower reptile diversity and abundance in long-unburnt mallee than more recently burnt. - more open ground foraging species in recently burnt mallee. Birds - in recently burnt mallee (<1 year) widespread opportunists most common; those more common 1-10 years are those not totally dependant on mallee; older veg favours endemic mallee species.

Fire regimes co-existence and management: Little evidence of adverse fire regimes in the large expanses of remaining mallee. Changes in landuse and human use may affect ignition rates in ways that are difficult to predict. The scope for an increase in human ignitions coincident with severe fire weather is high. Any resultant change in mallee fire regimes is likely to be significant. Discussion about the nature of fire regimes in mallee and interactions with biodiversity is typically focussed on intervention and includes technological suppression of unplanned fires, creation of fire trails and fuel breaks, prescribed burning and other methods of fuel manipulation. The need for intervention is supported by 'historical', 'mosaic' and demographic (or life history) paradigms. The idea that past fire regimes can be recreated and conservation of biodiversity will automatically ensue is unrealistic and impractical. The mallee landscapes are now unique from clearing, European land uses and population density and so knowledge of the interplay between biodiversity and fire regimes within a contemporary context is needed. The wilderness declarations in large areas of mallee and the increasing use of aircraft for suppression and strategically targeted control burning may reduce the need for trail and fuel break construction and heavy machinery for suppression which may have the adverse impact of increasing human ignition. In addition, wet years may make fuel breaks and prescribed burns more likely to carry a wildfire.

**Notes:** Encroachment of mesquite, burroweed and other noxious shrubs has seriously reduced the carrying capacity of thousands of acres of desert grassland ranges. This has been blamed on grazing and control of fires. Livestock controlled fire indirectly through removal of fuel by trampling and grazing. Same theory proposed by Leopold for encroachment of oak and juniper. This study tested these theories: shrub numbers not decreased greatly by removal of grazing. Although fire may have been an important factor, the hypothesis that fire originally maintained the desert grassland in a shrub-free state is questioned. Suggests that shrubs rather than grass were natural dominants in this area and grasses were dominant due to some factor unfavourable to shrubs.


**Notes:** Discusses the use of the rangelands across the world and the increasing human pressure resulting in desertification in the rangelands. Suggests that the damage from overgrazing is spreading while the world livestock population continues to grow with population growth. Degraded rangeland worldwide totals 680 million ha = 5x the US cropping area. A 1991 UN estimate of livestock production losses from degradation exceeded $23 billion.


**Abstract:** The effects of burning, clipping, applying nitrogenous fertilizer, and protection from grazing on populations of three perennial grasses were monitored over four years in permanent quadrats in a mulga (*Acacia aneura*) woodland pasture near Charleville, Queensland. The grasses were the weedy invader *Aristida armata* (wiregrass), and two desirable species, *Thyridolepis mitchelliiana* (mulga grass) and *Monachather paradoxa* (mulga oats). They comprised 70%, 16%, and 12% respectively, of the pasture at the start of the experiment. Rainfall had a greater effect on plant numbers, especially of *A. armata*, than any treatment other than repeated clipping. The greatest mortality amongst *A. armata* plants occurred during a protracted dry period between March 1982 and April 1983 but the losses
were more than compensated by mass germination during April 1983. The other two species responded similarly but less markedly. Repeated clipping caused attrition of all three species but failed to improve pasture composition. Pasture recovery after burning was slow and accompanied by a minor deterioration in pasture composition as measured by the proportion of *A. armata* plants. Burning caused greater mortality in *A. armata* plants than in the other two species but this was offset by greater *A. armata* seedling regeneration. Both initial survival and subsequent seedling recruitment were reduced by slashing a week prior to burning. When left ungrazed *T. mitchelliana* and *M. paradoxa* were more drought tolerant than *A. armata* and their relative numbers in the ungrazed plots increased over the four years of the experiment. Thus, protection from grazing offers the best prospect of improving pasture condition as none of the other treatments reduced *A. armata* numbers without adversely affecting those of *T. mitchelliana* and *M. paradoxa*.

**Notes:** Control of *Aristida* the object of the study. Rainfall the most significant factor in the relative abundance of three grass species. Destocking had some effect but needs to be for a very long time. Burning provided only short-term control and time of burn needs to be considered


**Abstract:** This manual aims to document the past and present research that deals with the management of thickening native shrubs in SWQ, to determine best practice management principles. It is also the aim of this manual that 'best practice' management strategies are extended to land managers, the community and other related organisations.

**Notes:** Rangelands of SWQ at European settlement were typically described as open woodlands with a grass dominated understorey. At that time there was a run of good seasons deceiving settlers into overestimating the capability of the land. Pressure also increased with the subdivision of runs in the 1950s. Higher grazing levels that desirable resulted in no grass to outcompete the native shrubs led to increased shrub densities. Rabbits - their influence is debatable some suggest they helped to control, others that they removed herbage and encouraged the shrub growth. Development of watering points has led to a more even grazing across the landscape and upset the ecological dynamic of this area. Grazing gradients out from watering points has often resulted in thickening of native shrubs close to water points. **Fire:** The direct and indirect (through grazing regimes) suppression of fire by European settlers that has resulted in the increase in native shrubs is documented by the 1901 Royal Commission. Confusion exists in the use of fire to manage thickening native vegetation as in many cases fire has led to increases in germinating native shrubs. Important to consider season, type of fire and grazing when using fire for shrub control. The complete eradication of native shrubs is neither desirable nor feasible and should not be the aim of any treatment since these shrubs form part of the biodiversity of any area. The principle aim should be to restore ecosystem structure and composition.
Management options: grazing management; mechanical management (crocodile, chaining/pulling, pushing, grubbing, stick raking, ploughing, blade ploughing, slashing, waterponding), chemical management & fire management.

Fire Management: Preferred control method but should be integrated with other methods and should include a planned follow up burn or burns. Timing is important: seedlings are more susceptible than adult shrubs; fire can stimulate germination and domination of some species and promote multi stemmed growth; requires grass fuel load of >1000 kg/ha to carry the fire through thickened vegetation; major limitation to using fire for shrub control is the difficulty in having sufficient fuel over a large area and over time, cover>10% can make a burn ineffective and unable to carry due to lack of fuel; it should be a part of the overall property management plan - issues include protection of life and property, human health, nutrient loss, soil erosion, biodiversity conservation, greenhouse gas abatement, preservation of aboriginal culture; best to burn in late winter/early spring with a hot dry burn - will control most shrubs and allow for grass regeneration with summer rains; winter rains can lead to prolific shrub germination; burning of pulled or resprouting shrubs is best in Autumn (higher mortality); permits required. Control is worth it: the short-term economic loss is well worth the long term gain. Burning and grazing management are a more affordable means of controlling encroaching woody vegetation than mechanical or chemical means. Germination of native shrub populations relies on the availability of water in the soil profile and soil temps need to be between 20-30 degs C. So, burn when temps >35 and <10 degs C. Mass seedling establishment is dependant on good rains following germination events but more thickening occurs from less spectacular more frequent germination. Grazing and trampling of pasture at the time of shrub removal are factors that may increase shrub density. Removal of shrubs that involve soil disturbance can lead to a prolific increase in shrub density. Lists features of the main shrub species including appropriate management techniques including fire.

Case studies, local initiatives: significant support by landholders for burning. Method of increasing the fuel availability is to implement water ponding to increase the likelihood of grass growth - method - destock, build water ponding banks, follow up burning. Encouraging results. Also slashing green turkey bush in runon areas of a ponding site generates rapid native pasture growth after suitable rain - this method could bypass a wait of up to 2 years for sufficient growth of fuel. In general the greatest need is to find ways of building up the fuel


Abstract: Costs and benefits of prescribed burning for shrub control in a representative 2000 ha paddock are estimated, based on anecdotal and survey data collected from graziers in the Western Division. For a hypothetical paddock, two burns were assumed to take place during the space of seven years. Costs include those for constructing firebreaks and controlling the fire. In particular circumstances, income from grazing may be foregone when
"spelling" the paddock prior to the burn, and also after the burn until rainfall has induced the regrowth and seeding of pasture. Benefits from prescribed burning include increased livestock production, primarily through higher lamb weaning percentages and wool cuts from the self-replacing Merino flock, reduced mustering time and improved surveillance of livestock, resulting in better control of pests such as blowflies, lice, feral pigs and foxes. Capital value of the land is also improved. Cash flows over a 20 year period indicate that prescribed burning for shrub control is profitable. Despite this, users should carefully assess the maximum area that property cash flows will allow for setting aside to burn when an appropriate season allows.

Notes: Widespread seedling germination primarily due to above average rainfall but also TGP decreases the competitiveness of grasses against shrub seedlings & suppression of opportunistic fire. Goats selective in species they feed on and inefficient for shrub control. Prescribed burning feasible but not regular or reliable, dependant on season & fuel. Paper evaluates the economics of prescribed burning - benefits of increased production, reduced mustering costs & land value. Costs calculated and prescribed burning considered a profitable shrub management practice with a 7 year burning interval.


Abstract: In recent times there has been considerable speculation about the sensitivity of fire regimes to the change in climate that may result from global warming. However most of the discussion to date has not involved rigorous mechanistic analysis. This paper reviews the current state of our understanding of the effects that climate change may have on fire regimes in Australia and presents a new analysis for southeastern Australia. Climate change scenarios for Australia are discussed and previous work on the effects of climate change on spatial patterns of spatially summed Forest Fire Danger Index is reviewed. Various attempts at process-based modelling of fire regimes and the effects of climate change are then discussed before a detailed case study is presented for the Australian Capital Territory region, using output from the CSIRO DARLAM regional climate model and the FIRESCAPE fire regime model. The effect of a 2XCO2 climate was to increase the overall frequency of fire but not to alter the spatial pattern of fire frequency in the model system. More fires occurred in autumn under the changed climate compared with that modelled for the current climate. It is proposed that the increase in fire frequency is more likely to be a function of a reduction in the probability of fire extinguishment rather than significant increases in fire intensity at the other end of the fire behaviour spectrum. Finally some cases of consequences of predicted changes to fire regimes for biological diversity are briefly discussed.

Notes: Of all the fire regime variables, fire frequency was the most sensitive to a change in climate in SE Australia

**Notes:** Chapter titles:

Part I: 1. Bushfires: A Darwinian perspective (Bowman); 2. Fire regimes and biodiversity: a set of postulates (Gill and Bradstock); 3. Making the invisible visible (J. Williams); 4. Fire and climate in Australia (Lindesay); 5. Uncertainty, environment and fire: research and policy issues (Dovers); 6. Ecology and environment: a discussion summary.

Part II Fire behaviour and fire regime science: 7 Fire behaviour: integrating science and management (Gould); 8. Sensitivity of fire regimes to management (Cary and Bradstock); 9. Fire behaviour, forest management and biodiversity conservation (Lindenmayer); 10. The role of fuel moisture dynamics in determining bushfire behaviour (Weber); 11. The role of fire behaviour and fire regime science - a practitioner's perspective (Bartlett); 12. Fire behaviour and fire regime science: a discussion summary (Cary).


Part IV Policy, institutional arrangements and the legal framework: 19. Institutions and bushfires: fragmentation, reliance and ambiguity (Handmer); 20. Economic rationalisation, fear of litigation and the perpetuation of disaster fires (Cheney); 21: Policy, institutions and the law (Tarrant); 22. Fire policy: an insurance perspective (Henri); 23. Connectivity (Wasson); 24. Policy, institutional arrangements and the legal framework: a discussion summary (Dovers).

Part V Indigenous land and fire management: 25. Frameworks to support Indigenous land managers: the key to fire futures; 26. Fire in a jointly managed landscape: fire at Uluru Kata-Tjuta National Park (Liddle); 27. Yanyuwa classical burning regimes, Indigenous science and cross-cultural communication (Baker); 28. Using and sharing Indigenous knowledge (Burrows); 29. Indigenous knowledge - can it improve fire management in the Sydney region? (Whelan); 30. Indigenous land management (Davis); 31. Indigenous land and fire management: a discussion summary (Lindenmayer).

Part VI Synthesis: 32. Observations on fire ecology (Krebs); Perspectives on fire research (Whelan); 34. Lessons from the COAG disaster management review (Galloway); 35. Learning to live with fire (Campbell); 36. 'Australia burning': a discussion summary (Cary); 38. Research and policy priorities: a synthesis.


Notes: Provides information about Invasive Native scrub (INS): what it is, why it is an issue, what plants are classified as INS, how clearing of INS is assessed, the INS tool of the PVP, methods of INS treatment, how much INS can be treated, maximum size of INS that can be cleared and additional restrictions.


Notes: Lush conditions brought about by record rainfalls throughout 1973 and 1974 over most of the western division and culminating in very dry conditions over Dec & Jan of the summer of 1974-75 created an extreme bushfire risk whenever there were lightning strikes. Spear grass 3-4 ft high covered 2/3 of the western division with fuel load of 2-2.5 tonnes / ha linking fire types which would otherwise be very different in fire behaviour. The final stages in the curing of the spear grass produced a very finely divided volatile fuel. The spear grass also served to create a fire hazard in the broad expanse of mallee country, which in normal years grows insufficient ground cover to carry a fire. Describes the locations and behaviour of the fires in some detail. 

Fire effects on native vegetation: Timber & shrub species - generally not severely affected; most of the less edible shrubs such as turpentine, hopbush and punty bush were shooting from basal buds within a month of the fire; taller trees such as belah, wilga etc have been slow to show signs of life but are recovering; Rosewood and warrior bush which shoot from the base will probably make vigorous growth but may be subject to heavy stocking by sheep and rabbits in the absence of rain; mulga on sandy country badly affected and probably won't recover. Only a small proportion of mature pine has been damaged while dense regeneration pine was rarely burnt. Native pastures - much of the burnt country has supported bluebush and saltbush which normally does not burn readily but after scorching they shoot readily from near the base of the plant. If good rains fall within a few weeks of a fire, the response of native pastures is very good; heavy rains on bare soil could create a serious erosion problem. Mallee - large areas burnt out; with good rains rain the mallee country will be much more productive than usual after 2-3 years, declining again after 4-5 years due to mallee suckering.

Mallee Country: practically the whole of the mallee country of the western division was burnt out except for the belt between Mt Hope and Roto which burnt in 1957-8 and 1969-70.


Abstract: This article describes how land settlement policies over a period of 100 years and shrub regeneration in parts of the poplar box (Eucalyptus populnea) lands in New South
Wales have had and will continue to have a major influence on the economics of grazing properties in the region. Choice of animals offers few options, but there are many methods of improving productivity which may be applicable to a particular property; their feasibility is being tested in a pilot rehabilitation scheme which is described.

Notes: Phases of shrub regeneration: soon after settlement in 1870s during long run of flush seasons to drought at end of century, 1949-1956, 1963-64, 1973-76; reduces carrying capacity. Poplar box lands - merino grazing, cattle only to eat excess forage in good seasons; with smaller property size need to improve productivity by manipulation of soil & veg to counteract shrub growth. Fire control feasible in fringe areas where grass abundant & shrub seedlings small enough to be killed, won't take in dense scrub. Contour furrows - extensive areas of sheet eroded hard gravelly ridges, water lost by runoff, improved infiltration improves carrying capacity. Other control - ringbarking & poisoning, herbicides, goats.


Notes: Contends that the degradation of much of western NSW has been reversed since the improved rainfall conditions in the 1950s. This view is contentious (Johns, Tongway, Pickup 1984) and rangeland degradation is probably continuing.


Abstract: Water-spreading to boost the production of crops and sown pastures on semi-arid grazing lands offers a means of bringing about large increases in productivity and earning capacity, and enables easier management of scrub-invaded lands in western NSW. Large areas of western NSW are being invaded by native scrub species with deleterious effects on the carrying capacity of the lands affected, and consequent disaster to the earning capacity of the properties so blighted. The area most seriously affected has been the level red loams and gravelly ironstone ridges of the Cobar-Byrock-Bourke region. The loss in productivity has led to serious land settlement problems, and economic and social hardships of the landholders affected. It is estimated that some 2 million ha and 180 properties are threatened. The latter figure has been reduced by probably about 10% by amalgamation of properties as landholders have endeavoured to take the only avenue for adjustment to the combined effects of sub-standard property size and loss of productivity due to scrub infestation. However it has been pointed out by the Inter-departmental Committee which has investigated the problem that increase in property size offered no advantage in improving earning capacity and merely aggravated the management problems of operating such
country. The disappearance of the ground forage species leads to a low plane of nutrition for livestock and serious water erosion as the bare soils under the dense canopy of scrub are exposed to watersheeting on slopes as low as 1%. Mustering was a time consuming task which added considerably to operational costs and made lice and blowfly control almost impossible. Consequently losses were high. Scrub regrowth brought about a situation in which decreasing returns and increasing costs reduced living standards on affected properties to poverty level and led to much increased debt loads. The situation was made worse by declining wool prices in the late 1960s and early 1970s.

The extremely high run-off from bare (although scrub-covered) ridges and lower slopes ensures large volumes of run-on into drainage lines and watercourses, known locally as flats or box cowals. The additional water to these areas has assured the development of larger and thicker scrub and timber regrowth so that the most productive parts of the former landscape have become the least productive.

Notes: Water spreading is a technique in which run-off from storm rains is diverted out of shallow drainage lines and watercourses and, by means of specially designed and constructed spreader banks, spread over broad flats. The hard red gravelly and often seriously eroded ridges typical of the Cobar-Byrock region yield a high proportion of run-off from relatively small storms and provide an ideal catchment for water spreading areas. Water spreading projects also involved clearing of the densely timbered flats.


Notes: In Nov 1976 there were 139 lightning strike fires in a 5 day period. The northern part of the western division carried a very heavy fuel load resulting from torrential rains 100mm-300mm in Feb 1976. As a result of these rains, being the 4th year in succession with abnormal summer rains, the heavier soils throughout the west Darling north from the Barrier Highway, carried a dense growth of Mitchell grass and Queensland Bluegrass to 1m high. The lighter soils of the sandy mulga country likewise carried a dense growth of wiregrass and kerosene grass to 1/2m. From the Bulloo Overflow eastward through Wanaaring and Enngonia districts and south to the Darling, pastures dominated by woollybutt to1/2m. Dense spear grass to 1/2m found to the south & east of the Darling. Areas not burnt in1974-5 carried relatively little fuel. Fire season started early August and Sept with small fires.


Notes: Relatively few fires in the 1979-80 season due to drought or near drought conditions producing a low fuel load and a low incidence of dry lightning storms. Southern and far western portions of the Division carried a moderate to low fuel load as a result of better seasonal conditions, fuel load decreased to the north.

Notes: Problems associated with grassland fire fighting can be classified as logistics, landscape and fuel type and weather. 

Landscape and fuel type: has a large bearing on type and quantity of fuel which are the main factors affecting fire behaviour - seasonal conditions preceding and during the fire season is the most important factor determining the fuel build-up. Tall grass 60-90cm high is by far the most abundant fuel type in the western division. Landscape fuel types - Mallee (dense & open), timber and scrub (Box, coolabah, ironwood, mulga & scrub - Bourke/Byrock/Cobar/Louth; box, pine, wilga, scrub - Mt Hope Nymagee/Cumborah; mulga, belah, rosewood, wilga, ironwood, gidgee, scrub - Paroo to Culgoa Rivers), floodplain woodland, open scrubland, treeless grassland plains, treeless saltbush and bluebush plains, timber (mainly mulga) and scrub on hills.

Landscape factors affecting fire fighting strategies: topography, soil conditions and the presence of timber and scrub. Topography - rate of forward spread doubles up a 10 deg slope, x4 up 20 deg slope and correspondingly decreased on downward slope; fuel volume decreases markedly with slope above 10 degs and fire likely to go out. Soil conditions - main influence is on fuel type. Timber & scrub - the more dense the scrub the lower the fire danger rating because grass fuels absent or dominated by low flammability species like copperburs; in most cases heavy timber heavy timber cover particularly belah and rosewood make an effective firebreak, mulga may carry a crown fire under extreme conditions.

Flammability: pastures will burn quite readily when only 60-70% cured provided that there is sufficient dried material around the base of the grass tufts and plants linked by dried material. Modified grasslands fire danger meter has been developed for measuring fire danger index and rate of spread for arid areas. Flame height, spotting (includes flaming animals), fuel moisture and weather discussed. Summary tables for different fuel types and their responses provided.


Notes: Only 18 fires in the 1980-81 season - drought or near-drought conditions - small area burnt low fuel load and very few dry lightning storms.


Notes: Greenhouse issues and carbon trading: In north Australia there has been a general increase in heavy rainfall over the past century. This trend in consistent with predictions from
climate models under enhanced greenhouse conditions. The frequency of extreme events such as floods and droughts will probably increase. The best predictions for precipitation are that wet season rainfall in north Australia could decline by up to 8%. By the year 2030, temps are likely to increase by 0.4-1.4 degs C inland and by 0.3-1.0 degs C in coastal regions of north Australia. As well as affecting climate the increasing carbon dioxide concentration are likely to lead to increased plant growth, trees and shrubs favoured over grasses. Higher temps may also cause fuels to become drier and rates of fire spread may increase with resultant rise in fire intensities + the expected increase in wind speeds.

Approx 30% of Australia’s human induced greenhouse emission are from land-management based activities including cropping, grazing, land clearing and forestry. Worldwide fires lit by people in savannas are also important sources of greenhouse gases that affect the atmosphere and climate. In Aust greenhouse gases from burning of savannas and grasslands comprise about 2% of total human sourced emissions of these gases. Most savanna burning comes from north Aust (WA (incl Hamersley’s & Pilbara) Qld NT) with only 2% from the rest (NSW, Vic, SA & Tas). Frequent fires keep the density of trees and therefore amount of carbon stored in savannas below what is possible for particular climates and soil types. In future carbon trading could allow the carbon storage in trees to have a commercial value that might offset reductions in pastoral productivity resulting from tree thickening. The challenge will be to develop burning strategies to optimise potential economic gains from increasing carbon storage as well as from sound pasture management.


Abstract: The preparation of a revised Fire management Plan incorporating environmental analysis was commissioned by the Mallee Bushfire Prevention Scheme in response to changed social attitudes about the environment. The aim of this plan is to establish why it is necessary that prescribed fire should be used in the mallee rangelands. Because the scheme is a bushfire prevention scheme, the use of prescribed fire for purposes other than hazard reduction also enters its ambit when used within the region. The plan is divided into three parts; Introduction, the Environment and Fire Management. A series of appendices contain maps, tabulated data and other pertinent information. The introduction aims to recount historical facts about the Mallee Bushfire Prevention Scheme and the region it covers and methods of wildfire mitigation currently used. The chapters on environment describe the risks posed to the known resources of the region by wildfire; and how and why wildfire suppression has been ineffective in the past in the mallee and adjacent rangelands. The final 2 chapters on fire management recount current operational procedures
of wildfire mitigation and suppression in the region. The objective of these chapters is to discuss alternatives to and refinements of existing procedures. It is envisaged the plan will provide a flexible set of guidelines for decision making and responses to various events and combination of events by bushfire brigades in the region. To this end it is the recommendation of this plan that the use of prescribed fire under controlled circumstances is the only feasible form of wildfire mitigation in the region.

**Notes:** Mallee Bushfire Prevention Scheme in the Cobar, Central Darling & Carrathool Shires; aims - construct & maintain fire trails through mallee and reduce patches to smaller manageable units & to reduce fuel loads along perimeters of mallee areas. Backburning is the only safe method of suppression suitable for mallee wildfires. The only effective form of hazard reduction is off-season burning alongside access trails because of ability of mallee fire to crown and spot. This provides a wider fire break. Fuel loads in mallee rangelands have increased since closer settlement since WWII. Past burning regimes (lightning, aboriginal, stockmen) produced a mosaic of areas with different fire histories. Extensive mallee wildfires in the western division recorded in summers of 1917/18, 1921/22, 1931/32, 1939/40, 1956/57/58, 1969/70. Others parts of the rangelands were burnt in 1974/75 & 1984/85. Estimated that serious wildfires occurred every 10-15 years and small areas more frequently. Mallee fire frequency directly related to rainfall, occurring after above-average rainfall seasons and ephemeral fuels such as variable spear grass are more important than perennials because they connect litter and triodia patches. Of the 3.75 million ha burnt Nov 1974-Mar 1975 nearly half was mallee in the Balranald, Wentworth, Central Darling & Cobar Shires. Describes 5 land types, soils and flora: Mallee, ranges & hills, hard red country, river floodplain country, red country.

Fauna; effect of wildfire largely unknown but in Yathong Caughley (1985) found 4 of 9 most abundant reptiles (burrowers that foraged in the open) more abundant in recently burnt sites. Mallee rangelands the most wildfire prone within the region. Fuel dynamics of wildfire prone mallee discussed in some detail - intensity controlled by surface temp, fine fuel quantity, rate of spread, heat energy; rate of spread controlled by fuel characteristics and weather. Fuel management strategies: hazard reduction - practice of removal or reduction of fuel to minimise fire risk, generally achieved by fire breaks or prescribed burning. The primary requirement for any fuel management strategy must consider fuel loads on probable wildfire paths. Pre-planning necessary for hazard reduction burns. Line burning method has least manpower requirements, and causes least harm to the total mallee environment. Prescribed burning v's mechanical hazard reduction - top soil not disturbed, effects longer lasting, nutrients returned to the soil. In addition to hazard reduction prescribed burning increases habitat and biotic diversity and forage (based on work by Jim Noble). Impact of uncontrolled wildfire on biodiversity thought likely to be greater than prescribed burns to control wildfire. Line burning, the removal of hazardous quantities of fuel from the probable paths of wildfires to protect the wider environment and its internal elements - considered the only appropriate prescribed burn strategy. Monitoring necessary to assess impacts. Extreme bushfire risk when fuel load is >12 tonnes/ha: litter covers >75% of surface within canopy dripline; areas covered by triodia form a continuous mat within and between coppice driplines; areas without triodia have dense swards of annual herbage which is flammable when cured (hayed off). When this threshold is being approached then prescribed burning is desirable.
Wildfire mitigation in the mallee: A period of perhaps only 4 weeks under appropriate climatic conditions can result in a change from low fire risk to extreme wildfire risk. There is therefore a need for ongoing hazard reduction. Corridor chaining - 80m wide corridors chained prior to backburning to reduce risk of spread of backburn - removes canopy and reduces spotting risk. Hazard reduction burns aimed to reduce fire intensity.

Wildfire control in the mallee: specifies operational procedures.


Abstract: This publication details the results of research during the 11 years to the end of June 1974. The previous grazing history is outlined and the vegetation, soils and climate of the area are discussed as well as the results of runoff studies. Details of the revegetation treatments and their effects on soil moisture levels and vegetative cover are included.

Notes: Studies were undertaken to determine the effects of stocking and rainfall on the growth, survival and regeneration of mulga, white pine and turpentine. There was an overall increase in numbers of woody species on all plots but little within the drought periods of Sept 1964-June 1969. Regeneration triggered by rainfalls in 1969. Small decreases also occurred. Different species composition had different regeneration patterns. Regeneration of mulga, white pine and turpentine is only slightly affected by grazing and that regeneration and rainfall are poorly correlated, at least under furrowed conditions. However regeneration has occurred over the past 10 years at Cobar. Regeneration of trees and shrubs suggests that there is an accelerating change toward a dense woodland and this will continue despite heavy stocking or spelling of country.


Abstract: About 25% of the sandplain landsystem near Shark Bay, bears evidence of pyric succession in its arid shrub associations. Unburnt areas are dominated by Acacia ramulosa. Burnt areas are support more open shrublands without much A. ramulosa but with numerous palatable low shrubs especially Ptilotus obovatus for at least 40 years after burning.

Notes: Major fires in the area thought to have been ignited by electrical storms fuelled by unusually heavy seasonal growth of annual grasses mainly Aristida contorta. In most years there is insufficient fuel to support local fires. In these circumstances: 0-4 years - general death of A. ramulosa, some survive by resprouting, little germination but Codonocarpus cotinifolius and Gyrostemon ramulosus can become dominant; 4-15 years - Codonocarpus and Gyrostemon
die, other acacias and *Grevillea stenobotrya* dominate a scattered tall shrub cover, *Ptilotus* and *Solanum* dominate denser low shrubs; 15-50 years - tall shrubs (mostly various other acacias) dominate or in overgrazed communities *Stylobastium* and *Eremophila* dominate, slow recruitment of *A. ramulosa* which can be co-dominant after 40 years; 50+ years - probably reverts to denser tall shrublands of *A. ramulosa* as faster growing pyric species senesc and die, low shrubs decrease. The grazing usefulness of the system seems to lie in complementary resources of burnt and unburnt areas. For pastoral purposes a fire cycle of 20-50 years is probably desirable in this system.


**Abstract:** The range of grass, shrub and tree levels present in the Louth region of western New South Wales was determined in an area where woody weeds are considered to be rampant, and the prospects for change by burning were evaluated. Relationships between the three vegetation elements in each of four major landforms were determined by regression and reduction in the canopy cover of woody vegetation after one or two fires were simulated. Basal cover of grass was negatively related to canopy cover of woody vegetation, except in the Sandplains and Dunefields landform. The relationship here was curvilinear with maximum grass cover occurring at 10% canopy cover of the woody vegetation. Pastoralism was considered to become less efficient when the canopy cover of woody vegetation exceeded 5%; 44% of sites measured were below this threshold. The remaining sites could be divided into two groups; one which would fall below the threshold if burnt with a prescribed fire (21%) and the other which required two fires or an equivalent second treatment to reduce the cover below the threshold (35%). The survey confirmed the perception of pastoralists, administrators and scientists that shrub cover is unacceptably high for pastoralism throughout much of the region. Additionally the perennial grass cover was very low and this would increase the instability of forage supply to pastoral herbivores. The high spatial variability in the composition of vegetation indicates that graziers need to identify and treat areas where return on investment in rehabilitation will be highest and most certain.

**Notes:** Measured perennial vegetation on 4 landforms (sandplains, rolling downs & lowlands, plains, alluvial plains) near Louth NSW in semi-arid woodland and grasslands to determine cover & composition of perennial vegetation & to predict canopy reduction of woody vegetation after fire. Found that the interrelationship between trees, shrubs & grasses without fire depends on landform - woody plant density is associated with lowered basal cover of grasses except on sandplain & dunefields. Palatable perennial grasses can also be encouraged to grow, even in the presence of dense woody shrubs by resting from grazing & reduced TGP. Benefits of fire can be long lasting but shrub regrowth & potential erosion mean that it must be viewed as part of a property management plan and not as a one off treatment. A second fire 12 months later in autumn kills up to 80% of regrowth or herbicide could be applied to simulate a fire (see Noble *et al*).

**Abstract:** We address a number of management principles pertaining to temporal and spatial changes in rangeland systems. Both plant community composition, and availability and quality of forage, are temporally variable. The process of community change, at least in southern Africa, appears to differ between humid and arid environments. In humid environments, change follows a relatively gradual and predictable pattern, with both over- and under-grazing resulting in decreased carrying capacity. Factors other than grazing also cause change. In arid environments, change is event-driven, providing the grazier with risks and opportunities to cause or prevent community change from one state to another. Humid and arid rangelands also exhibit different patterns of inter- and intra-seasonal variation in forage availability and quality. In the former, changes, particularly in quality, are relatively predictable, allowing the grazier to match forage demand to supply, thus facilitating stable animal husbandry systems. In arid ranges, the profound change is inter-seasonal forage production, implying unpredictable carrying capacity. Flexibility in livestock numbers is therefore essential. Spatial heterogeneity of rangelands results in patch utilisation and localised deterioration of varying scale. In southern Africa, the traditional response has been fencing, an expensive and sometimes impracticable solution on an extensive scale. Fire and siting of artificial water points or mineral licks are alternative options for redistributing animals. The interaction of spatial heterogeneity with temporal rainfall fluctuations in arid rangelands provides pulses of productivity varying in space, time and magnitude. Settled pastoralism is perhaps unsuited to these environments. Finally, in view of the complexity of rangeland systems, and the paucity of empirical predictions for graziers, we suggest that formalised adaptive management - decision-making from past mistakes and successes - is the most appropriate means for graziers to cope with a changing environment.


**Abstract:** Broad changes to vegetation cover (considered as wildlife habitat) and the distribution and status of fauna in the Western Division of NSW are recognised from a study of historical records. Explorer’s journals, diaries, notebooks and maps are examined and the roots of the major explorers retraced. Areas where countryside was described in detail are examined and an assessment made of any changes that have occurred during the last 150 years of European settlement. The study area is divided into five environmental regions (as described by CSIRO) and a total of 98 sites are surveyed.
From this study it is concluded that there has been an overall decline in the amount of vegetation cover, either as trees, shrubs or grasses and forbs, with nearly 50 per cent of the sites surveyed showing a decrease in land cover. Also a total of 7 mammals and 11 bird species appear to have declined in population status in inland NSW since European settlement.

**Notes:** Provides summary of previous assessments of conditions in the western division, all of which have been determined without the knowledge of any baseline 'pre-European data. Also provides a summary of dates relevant to the changes in the environment in inland NSW from the squatting era beginning in 1830 to 1992. In the study reported in this paper the locations directly described in explorers journals are revisited and compared with the original descriptions. Quantitative evaluation was based on regions of similar environmental conditions.

**Results:**

- **Region 31** - arid western half of the western division crossed by Sturt and Bourke & Wills - Sturt had difficulties in passing through scrub and timber in an area that today hardly contains any upper storey vegetation (‘a dense brush of pinetrees, acacia and other shrubs growing on pure sand. Through this we rode for more than 15 miles, to the great labour of the animals as the soil was loose, and we had constantly to turn suddenly to avoid the matted fallen timber.’ About a third of the sites showed some decrease in vegetation cover, greatest change in loss of tree cover.;

- **Region 29** - NE Broken Hill, riverine plains west of the Darling - 40% of sites showed some decrease in vegetation cover, little chance near Rivers but extensive clearing has occurred on the broad riverine plains - Northern Hairy Nosed Wombat commonly observed by explorers.;

- **Region 28** - north-east of western division and western slopes and rivers (Moree to Warrumbungles and west) - 58% sites showed some decrease in vegetation cover due to clearing. Possums and bandicoots decreased. Frequent mention of high numbers of kangaroos and emus - little evidence of decline.;

- **Region 32** - large region including Broken Hill, south the Murray and east to edge of central division, riverine plains. Only a few sites showed a decrease in tree and shrub cover and less than half site had decreased grass cover. Little change along the riverland between the Ana Branch and the Darling was covered with 'dense and dreary brush' according to Sturt but is no longer present. Pig footed Bandicoots present - last one collected in 1907.


**Notes:** Plan covers most of Victoria's mallee which is in the Mildura District in the north-west of the State. It also includes river red gum & black box woodlands, heath, grassland and saltbush &blue-bush shrublands. Altered fire regimes have been identified as threatening processes to heath communities with *Banksia ornata*. Other veg communities such as pine-buloke woodland (Listed as Threatened under the EPBC Act) are sensitive to fire and may need active protection. In mallee-heath rare & threatened plant species are not disadvantaged by fire and were generally more abundant post fire. Fire suppression can result in weed infestations. Triodia provides specialised habitat for a number of faunal species. Reptiles (e.g.
Butlers Legless Lizard), mammals (Mallee Ningaui), birds (Mallee Emu-Wren) are considered to be triodia specialists. Fire removes that habitat which may not return for considerable time. Some of these species may be in decline due to a series of large fires. General approach is has changed from fire protection plans to fire management plans.

**Management** - Fuel reduction burning in mallee to contain wildfires, other methods also used.

**Maintenance of rare & threatened wildlife habitat:** Historical management of fire in the Big Desert had resulted in the progressive simplification of the ecosystem with the common, generalist, widespread, fire-tolerant, highly fecund or mobile taxa persisting & rare specialised, localised, high site fidelity, fire-sensitive, low fecund, or low mobility taxa in decline (eg malleefowl, striated grasswren, western whipbird, western blue-tongue, bardick, heath monitor, Mitchells hopping mouse). Post fire vegetation is uniformly even aged and species dependent on successional stages are disadvantaged. In addition the more intense the fire the less likely there are to be unburnt patches remaining which may sustain population nuclei for recolonisation. Minimisation of landscape fires by use of prescribed burning is a key long term objective.


**Abstract:** The Western Division of New South Wales is an administrative region of 325000 sq km on the eastern fringe of the Australian arid zone. Since European settlement in 1788 71 species of native mammals have been recorded in the division, seven more have been documented only as sub-fossils, and a further 15 species occur within 100 km of the divisional boundary. At least 27 of the original species have become regionally extinct, and a further 11 have declined in distribution. As in other regions of Australia, species losses have been greatest for rodents and marsupials in a critical weight range of 35-5500g, and least for bats. However, percentage losses among the terrestrial fauna are high relative to other regions, and probably reflect both the early settlement of NSW and the marginal distribution in the Division of 49% of the original fauna. Feral cats are implicated in the regional extinction of up to ten species of native mammals prior to 1857. Subsequent extinctions and range reductions are attributed to a combination of causes, including predation from cats *Felis catus* and red fox *Vulpes vulpes*, competition and habitat degradation from rabbits *Oryctolagus cuniculus*, stock and other introduced herbivores, clearing of trees, changes in fire regimes and human persecution.

We identified 28 species of particular conservation concern in the Division based on low abundance, distribution or survival prognosis. Nine species are of national significance, and 15 of regional significance. The major current threats to these species are from grazing by stock, interference from feral mammals and clearing. Further land reservation is an important conservation measure, but must be complemented by more effective management of non-reserved land and by broad-scale management of feral species and other threatening processes if the current species diversity is to be maintained. Long-term fauna surveys should be initiated throughout the Western Division to provide feedback on the effectiveness of
management measures, and species reintroductions should be considered in situations where threats have been removed.

Notes: Provides an analysis of the mammal species recorded from the western division from a variety of historical sources and an assessment of their distribution and status in the 1990s. Patterns of faunal change (extinction, range reductions and expansions) are discussed and survival prognoses (based on phylogeny, ecology and body size) for the remaining species determined.

Faunal declines: interpretation and causation - First wave of extinctions 1840-1900, due to feral cat. Stock & rabbits also caused retreat of native species through depletion of long grasses and shrubs used for shelter, dietary competition, shallow burrows destroyed and erosion exacerbated.

Changed fire regimes: Aboriginal use of small scale fires lit throughout the year - produced a mosaic of different aged patches of vegetation that maintained low fuel loads and prevented broadscale fires. This was removed by European settlers. This has been suggested as the reason for the loss of some species in WA but not supported by work in the Flinders Ranges. In the western division the effects of fire induced vegetation change are unclear. In the period about 1850 to 1880 continuous grass cover was created in many districts by annual autumn burning and extensive subsequent grazing by stock (only possible in southern regions) - in these regions 'improvement' of pastures had occurred by 1866 - 9 years after the last records of 8 species. After the cessation of annual burning in the 1880s uncontrolled fires have swept the Western Division several times. The interaction of changed fire regimes with grazing has allowed the proliferation of woody shrubs. Overall, multiple causes are implicated in the decline of mammals in the western division.


Abstract: Effects of 20 years of prescribed burning on infiltration rate, sediment production and runoff water quality were evaluated for a longleaf/pinehill bluestem association in Louisiana. Immediately following prescribed burning, increased raindrop impact on bare soil decreased infiltration rates and elevated suspended sediment over the unburnt plots. However 10 months after prescribed burns these differences were insignificant. No significant nutrient losses due to prescribed burning have been detected. Burning may impact soils by accelerating erosion, decreasing infiltration and water holding capacity and reducing water quality. Prescribed burning may accelerate fertility losses or increase short-term nutrient availability.


**Abstract:** Woody weeds are generally not seen as a problem in the arid and semi-arid rangelands of SA. However this series of photos demonstrates that given the right seasonal conditions and heavy grazing, woody weeds such as hopbush (*Dodonaea* sp) can become established on certain soil types. Series of photos from 1973 to 1991. By the time hopbush seedlings were firmly established in 1980 permanent change in the vegetation composition was inevitable. It is possible however that had the paddock been conservatively stocked from 1973 onwards, thereby maintaining a higher level of pasture cover, that the present day density of hopbush would not be near as great.


**Abstract:** Examination of data on dietary preferences of sheep, goats and cattle suggests that different grazing systems are desirable for each of the three major woodland types (belah-rosewood, mulga, poplar box) examined. Competition for herbs, frequently palatable to all animal species, indicates that goats and sheep are unsuitable for joint use either in heavily wooded country or where annual herbaceous production is less than 200 kg-ha. Supplementary feeding, fire and judicious stocking are proposed as a strategy for inducing goats to eat a proportion of unpalatable shrubs. The literature provides little helpful information on how rangelands in the Western Division should be managed. No reports are given on comparisons of grazing systems, such as rotational grazing, rotational resting, and continuous grazing. No guidance is given on grazing after burning of the rangeland. Recommendations are generally against the use of goats for control of woody plants, whereas local observation shows this to be an apparently effective practice. The recommendations are mostly based on experimental procedures which, although suitable for detecting animal dietary preferences in the short term, are less appropriate for investigation of the effects of grazing on range condition in the long term. Some suggestions are made towards a different approach for: investigating the effects of grazing by sheep and goats on rangeland condition, and the economic implications of this in terms of animal production.

**Notes:** Lit review of grazing trial - indicates that they are not suitable to assess the long term impacts of grazing on rangeland condition. Local suggestions that grazing after fire is useful for shrub control but this has not been assessed.

**Abstract:** One hundred and ten paddocks were surveyed to give an overview of the effects of management burning, grazing by cattle, goats and sheep, and protection from livestock, on major vegetation types in the rangelands. A commercial paddock scale was used to complement information previously available on dietary preferences of livestock from a few, small research sites. In this dry period study, estimates of woody and herbaceous cover were not significantly different overall among paddocks subjected to the various kinds of management. However, herbaceous cover in protected or spelled paddocks was better than in the others. Also, no significant relationships were found between woody cover and herbaceous biomass in any treatment. Despite moderate sample sizes, high coefficients of variation occurred throughout the results. These were regarded as being a true reflection of the variability between paddocks in the rangeland. Underlying differences between management types may have been masked by the heterogeneity of the paddocks within each type due to a complex history of rainfall, burning and grazing. Cluster analysis of the 110 paddocks revealed floristic (woody spp.) similarities of mulga, poplar-box, pine and some belah-rosewood woodlands, whereas saltbush and mallee were distinct. Further comparisons of management types were made on mulga woodland alone. Domestic goats were kept in the most heavily wooded paddocks and, in contrast with sheep, checked the growth of woody plants < 2m high. Woody growth recovered in the < 2m stratum several years after burning. Further evaluation of the herbaceous layer and of woody/herbaceous relationships is recommended after a wet summer.

**Notes:** Critical factors in producing significant biomass variations in study - rainfall, stocking history, fire history and these were not always evident. Low (<2m) woody shrubs promoted by sheep grazing, reduced by goats, not much affected by occasional burn. Spelling of pasture most likely to improve condition.


**Notes:** Contents
1. Introduction - background
   Part A. Review of the Impacts of Climate change on Biodiversity
2. The Palaeo context
3. The Impact of climate change on biodiversity
4. Synthesis of impacts: so what's going to happen? What do we need to know for conservation?
   Part B. Regional impacts of climate change


Notes: Using fire to manage tree and shrubs: The balance between trees, shrubs and grass throughout the northern savanna systems has probably always been changing, mostly in relation to variable fire regimes and rainfall. Tree and shrub increases and thickening has been recorded throughout many grasslands and open woodlands across northern Australia. Fire is the most effective tool to manipulate the amount of woody vegetation in uncleared savanna landscape. Management of trees that regenerate profusely following burning, whether they be obligate seeders such as mulga or turpentine or vegetative resprouters such as needle bush relies on periodic burning over a number of years.


Abstract: Pastoral managers in savannas face difficult decisions about trading off short-term use of grass biomass for animal production against its longer term use as fuel to manage tree–grass balances with fire. This study develops a model to represent the interactions between seasonal variability, fire behaviour, tree response, pasture growth and condition, grazing utilisation and animal productivity in a grazed savanna ecosystem. It successfully integrates simplified versions of several existing models, results of local research and expert knowledge to permit economic evaluation of tradeoffs given various fire treatments. The
modelling framework also enabled the effects of wildfire events to be simulated and allowed fire and livestock management costs and revenue to be quantified. Applied to one site and climate sequence, the initial results assuming constant stocking rates show the importance of burning for the long-term maintenance of productivity, and suggest that some level of late dry season fire is needed for this. Net present values of applying different fire regimes over different time horizons emphasise the factors that pastoralists must take into account in making decisions about preferred fire regimes.


Abstract: We describe the rationale, methodology and preliminary results from a major monitoring program in Kakadu National Park, northern Australia. The program aims to assess fire regimes, their impacts upon biodiversity, and the consequences and efficacy of fire management. The program comprises two complementary elements—mapping of fire histories based upon interpretation of satellite imagery, and assessment of vegetation at a large series of permanent monitoring plots. The program commenced formally in 1995, at which time establishment and baseline sampling of vegetation in 134 plots was conducted, with re-sampling proposed at 5-year intervals up to 2010. The monitoring program has an estimated annual cost of about $A140 000 (around 1% of the total annual budget of the Park).

Over the period 1995–2000, the mean annual extent of burning was 40.3%, a marginal reduction in extent from the previous 15 years, particularly for late dry season fires in lowland habitats. From the baseline (1995) and subsequent re-sampling (2000) of the vegetation plots, 963 plant taxa have been recorded. The power of the program to detect change in the frequency or abundance of individual species was poor, especially for ground-layer species, largely because of typically substantial variability in abundance across plots and sampling events, and because of the high proportion of species recorded from few samples. Notwithstanding this constraint, five tree species (of 47 recorded from sufficient samples to test), nine shrub species (from 121) and 27 ground-layer species (from 111) showed significant change in abundance between the baseline and subsequent sampling. However when species were grouped into strata and life-form categories, major changes were evident over this 5 year period, particularly with increases in cover of trees and shrubs. Such changes were related to a range of environmental and fire regime parameters of the plots, with increase in woody cover but reduction in cover and species richness of herbs in those plots experiencing lower frequency of fires.

**Abstract:** Over the last 130 years, patterns of land use in central Australia have altered dramatically, and so too have fire regimes and fire management objectives. Although Aboriginal people still have tenure over large parts of the landscape, their lifestyles have changed. Most Aboriginal people now live in towns and settlements and, although fire management is still culturally important, the opportunities for getting out on country to burn are constrained. Large parts of the landscape are now used for pastoral production. Under this land use the management objective is often one of fire exclusion. The other large-scale land use is for conservation. Here, fire management has a greater focus on conserving biodiversity using various burning strategies. In this paper we explore contemporary fire regimes in central Australia. Widespread fire events are found to be associated with two or more consecutive years of above-average rainfall. Although most of the fires linked with these high rainfall periods occur during the warmer months, in recent times these fires have exhibited increased activity during the cooler months. There has been a concomitant increase in the number and size of these fires and in the number of fires associated with roads. We also explored current fire management issues on Aboriginal, pastoral and conservation lands. Current fire management goals are not being wholly met on any of these land tenures in central Australia and social conflict sometimes emerges as a result. There are overlaps in management aims, issues and the under-achievement of desired outcomes across the land tenures which lead us to five key recommendations for improving fire management outcomes in central Australia. We finish with some comments on associated opportunities for livelihood enhancement based on the management of fire.


**Abstract:** Under a simulated rainfall of 45mm/hr, cryptogams significantly reduced splash erosion from a semi-arid red earth soil. As cryptogam cover increased, there was an exponential decline in total splash erosion and an increase in the proportion of coarse material in the sediment. For plots with 50% or more cover, sediment removal was constant over time. At <50% cover, however, sediment removal increased with time and failed to reach equilibrium. The results indicate that, under natural rainfall conditions, there is a continual transfer of fine material and adsorbed nutrients away from areas of low cryptogam cover.

**Notes:** Study conducted in Yathong Nature Reserve

Abstract: Measurements were made of density, size and shape of colonies of the soil lichen Psora crenata at sites with varying disturbance histories at Maralinga in arid South Australia. Lichens were measured along transects at 10 sites with recovery intervals ranging from 3 to 42 years, and on four undisturbed control sites. As the time since disturbance increased, the number of lichen colonies increased markedly, colony size declined, but colony shape remained unchanged. We tentatively suggest that at least 60 years is required for disturbed sites to approach the condition of undisturbed sites. These results reinforce the notion that lichen recovery is very slow, and suggest that colony density of Psora could be a useful indicator of recovery after disturbance in rangelands where crusts are a common component of the soil surface.


Abstract: Field studies were undertaken in a semi-arid woodland in eastern Australia to study the role of the funnel ant (Aphaenogaster barbigula) in infiltration and bioturbation. Ponded infiltration on soils with ant nest entrances was three times that on soils with no nest entrances and the presence of nest openings allowed water to reach significantly lower into the soil profile. The nest building activity by the ants was more pronounced during the warmer months. The ecological implication is that the presence of ant nests accentuates the development of moisture-rich patches in an essentially semi-arid landscape.

Notes: Study site at Yathong Nature Reserve. Sandy soils.


Abstract: Runoff and sediment yield were investigated on a sandplain dominated by woody perennial shrubs in north-western NSW, Australia. The site was bladeploughed; and some plots were grazed by sheep and cattle and others exclosed from grazing. Two years after ploughing and exclosure, grazed plots had significantly lower levels of aggregate stability and organic carbon compared with ungrazed plots, but there was no effect of ploughing. Surface pH levels were significantly greater in ploughed plots compared with ploughed plots. Two years after treatment, runoff and sediment yield were greatest on plots with the least disturbance (unploughed and ungrazed) and least on sites with the greatest disturbance (ploughed and grazed). We attribute differences in soil hydrology to the development of a
thin physical soil crust on the unploughed-ungrazed sites which restricted infiltration. On the ungrazed plots increases in plant cover and biomass and colonisation of the physical crust by biological elements are hypothesised to lead to reduced runoff and sediment yield over time.

Notes: Improved soil hydrology is normally associated with increase vegetation biomass and soil biological activity.


Abstract: Chapters:
1 Introduction - describes soil crusts, especially those in the arid and semi-arid west of NSW.
2 Role of biological soil crusts in dry environments
3 Components of soil crusts
4 Recognising and identifying individual soil crusts
5 Biological soil crusts in the managed environments

Notes: Lichen dominated soil crusts occur through the rangelands in western NSW, SW Qld and across southern Australia. In dry environments soil crusts reduce water and wind erosion and low to moderate rates of grazing (up to 0.75 sheep/ha) destroys large areas of crusts. Water infiltration is critical in dry environments. Soil crusts have been shown to influence runoff across the soil surface and water flow through crusted soils is likely to be influenced by the condition of the soil underneath. Crusts probably promote infiltration in severely degraded soils by providing small passageways produced by fungal hyphae and root like structures of lichens through which small amounts of water can penetrate. Nitrogen fixing bacteria are critical to the nutrient status of the soil and soil crusts incorporate organic carbon produced by photosynthesis directly into the soil system. They also provide niches for plant seedlings and invertebrates.

Landuse impacts on biological soil crusts: soil crusts are susceptible to overgrazing which leads to the demise and death of individual lichens and bryophytes. Fire - occasional burning probably has little or no effect on soil crusts but continuous burning kills the lichens and bryophytes, destroys fungal hyphae and breaks down the cementing gel that holds soil crusts together which leads to reduced water flow through the soil, reduce soil stability, increase erosion, and loss of productivity. It also decreases the niches for soil microorganisms. Results from mallee - takes about 15 years for soils to recover to their pre-burn cover levels after a single fire. Fires can also alter the composition of the crusts so that frequent fires less than 10 years apart can lead to a sparse cover dominated by cyanobacteria.

Abstract: Executive Summary: The relationships between regrowth, ground cover and erosion are discussed in relation to the semi-arid woodlands of eastern Australia: ground cover & erosion, regrowth & ground cover, regrowth & erosion. Ground cover refers to a wide variety of soil surface cover features including persistent plant litter such as bark and logs, ephemeral or non-persistent litter, stones, animal dung and non-vascular plants (soil crusts); 'groundstorey vegetation' describes live (and dead) plants such as grasses, herbs and forbs (vascular plants). The role of regrowth in conserving soil conditions, carbon storage, salinity mitigation and the provision of habitat and biodiversity.

Conclusions: It is not possible to directly link increased soil erosion solely to the existence of regrowth; the most important determinant of erosion potential in semi-arid environments is the amount of ground cover. Reductions in ground cover will result in an increase in erosion potential and the risk of erosion in areas of regrowth will be moderated most effectively by the management of ground cover; dense stands of regrowth can lead to reduced groundstorey vegetation but this may be compensated for by increases in other forms of ground cover particularly twigs and litter and living soil crusts; other factors relating to management might be involved in the initiation and increase of erosion but the relative impacts of grazing, trampling, soil compaction, fire and other management factors on regrowth and erosion are poorly understood; regrowth provides habitat and biodiversity, the improvement of soil condition and the mitigation of salinity; regrowth may also provide cost-effective and targeted revegetation of some landscapes, with potential value for carbon, salinity and environmental services trading.

Recommendations: Attempts to reduce erosion should focus on management actions that maximise the various components of ground cover that can intercept rainfall, enhance infiltration and trap sediments. Investigations that explore the relationships between regrowth, grazing pressure, groundstorey vegetation and ground cover are high priorities, but with recognition of the social factors relating to this issue.

Notes: Using old maps the Tullamore-Tottenham-Condobolin area was dominated by Eucalyptus and Callitris woodlands in the period 1870-1900. Densities of 6.1 to 40.7 trees/ha indicate that mixed box/pine communities were widespread west of the Great Divide - probably includes trees >40cm dbh and not shrubs, saplings or small trees. The structure of the vegetation varies from shrub woodland to tall woodland dominated by poplar box, white cypress, rosewood, wilga, and some grey box and inland red box. Often the selective removal of pine from these woodlands has given the impression that the poplar box is the dominant species. These veg communities are highly variable in internal structure reflecting variation in soils and geomorphology - banded or patterned landscape - common in semi-arid woodlands - one sheds water and nutrients and the other traps them. This is strongly controlled and maintained by rainfall and grazing pressure and the redistribution of water between these two patch types controls how the landscape functions, its productivity and the biodiversity it supports.
**Disturbance and pastoral management:** Intense grazing reduces grass/herb cover and their transpiration but low or moderate grazing stimulated plant growth through mobilisation & redistribution of resources. Overgrazing reduces root growth, biomass and nutrient uptake by ground storey plants, increases the proportion of bare ground between trees and shrubs, alters spatial arrangement of the landscape and reduces the efficiency woody patches capture and store water, sediment and nutrients. Fire - low intensity, short-duration fires are unlikely to have any deleterious effects on the soil or perennial vegetation.

Regrowth and carbon storage - Large quantities of carbon might be stored in regrowth although there are difficulties in quantifying and attributing changes in carbon stock under regrowth woodland - the size of the potential carbon sink in regrowth woodland has not been fully quantified - it is also possible that regrowth cannot be considered Kyoto compliant and therefore not accounted in greenhouse calculations or traded on the carbon market. The potential carbon sink offered by regrowth is large - maybe 27 million tonnes per year. This does not include below ground carbon storage which can increase the carbon by 30%. Also discusses regrowth, biodiversity and habitat.


**Abstract:** The aim of the study is to ascertain whether pasture degradation occurred in the Western Division of New South Wales in the last century, and to identify the causes of any degradation. A multidisciplinary approach, integrating the relevant work of agricultural scientists, botanists and economists into an historical framework has been attempted. In the literature it is argued that pasture degradation occurred in the period from 1880 to 1902 and this study has concentrated on that period. Several possible factors relating to degradation have been isolated and studied in turn. The important aspects of these factors are then combined into an analysis of the Division. It is demonstrated that degradation did occur and that it was directly caused by overstocking, which in turn was caused by economic pressures, and by the deprivations of the rabbit plague.

**Notes:** Correlations between rainfall and sheep numbers across the western division but it did not exist in the period 1895-1900. In this period the reduction in sheep numbers lagged considerably behind the reduction in rainfall. When the deprivations of the rabbit plague are considered with the overstocking, it is apparent that pasture degradation did take place. This was a period of economic pressure.

Abstract: Fire is a significant determinant of vegetation structure in Australia's savannas and has been implicated in the decline of many species. Identifying the patterns of fire in the landscape is fundamental to understanding vegetation dynamics but variation over time and space makes generalization difficult and specific management recommendations elusive. In order to improve the knowledge base for fire management in tropical savannas, we investigated interregional variation in fire patterns in two Queensland bioregions, the Mount Isa Inlier (MII) and Cape York Peninsula (CYP), over a 5-year period (1999-2003). Remotely sensed satellite data were used to identify burnt areas on a monthly basis for the western half of the CYP bioregion and about two-thirds of the smaller MII. Fire scars were mapped from JPEG-compressed, low-resolution Landsat images using geographical information system technology and data were investigated to determine annual burning patterns. Patterns were interpreted with regard to meteorological information and recent fire history. The area burnt per annum on western CYP was generally an order of magnitude greater than the area burnt on the MII. In the biggest fire year, nearly 74% (5,295,098 ha) of the CYP landscape burnt, compared with 35% (1,770,771 ha) of the MII landscape. The minimum percentage of the CYP study area burnt in 1 year between 1999 and 2003 was 43.1%, compared with 1.6% for the MII. The reliability and amount of seasonal rainfall was a strong determinant of differences in time of fire occurrence and area burnt between regions. Widespread wildfires were significantly related to above average rainfall in the preceding 12 months in the Mt. Isa area but not in CYP. Rainfall also affected fire frequency. Predictable wet season rainfall on CYP allowed for a biennial fire return interval, while on the semi-arid MII, the average fire return interval was 5 years or longer. We conclude that the fire patterns in the semi-arid MII are similar to those reported for arid Australia, while fire patterns in western CYP are comparable with other mesic savanna areas.

Notes: In tropical savannas some vegetation types are threatened by an increase in the incidence of late season wildfires and too frequent burning while others are threatened by the absence of fire (e.g. western NSW). The results from this study suggested that the pattern of fire in the semi-arid Mt Isa Inlier had more similarity with arid Australian landscapes than mesic savannas. The area burnt annually was highly variable and strongly associated with seasonal occurrence of rainfall and area burnt - related to fuel growth. Fire return interval was 4-5 years or more.
Notes: This booklet sought to address the pros & cons of burning for pastoral management in the desert uplands region of Qld (Barcaldine to Charters Towers). Not simple as even experienced bushmen disagreed about the effects of fire - probably reflects different landscapes and purposes.

Fire & land-use history of the desert uplands: Summary of historical fire patterns. Graziers views. Ignition by lightning during early wet season storms + aboriginal people probably burn whenever they traversed country with sufficient fuel and at any time of the year. With pastoralism grazing has reduced fuels but there is still plenty of scope for burning by pastoralists - demonstrated by the use of fire by 86% of commercial beef producers in central Qld to control woody weeds, for pasture management and to reduce fire risk.

The desert uplands landscape: Physical and cultural landscape. 400-600mm rainfall pa, 50% in one summer month but Second half of the 20th century had the wettest times with exceptional rains in 1950s & 1070s + substantial droughts between 1992 & 2002. Vegetation thickening: Ironbarks, box trees, Eremophila mitchellii, wattles & currant bush (Carissa sp). Acacia scrubs do not grow much grass and can act as natural fire breaks - fire occurs most commonly in the eucalypt country where perennial tussock grasses provide fuel. Spinifex burns well as does African buffel grass. Fuels dramatically reduce in low rainfall years especially with grazing & can be slow to recover because of low fertility. Where neither spinifex nor buffel are abundant effective burning may only be possible after wet years.

Vegetation thickening and dieback: Studies clearly demonstrate that this has occurred but rates vary from slight to substantial. The pattern of change seems to match the historic rainfall pattern with a quarter of woodland trees (especially ironbarks) were killed in the 1992-6 drought - this mortality is greater than fire related death. Also for the 1904 drought. Given that the droughts of the early pastoral period were sufficiently sever to substantially open up the country and that germination and growth of woody plants exploded in the 1950s it is probably not surprising the woody thickening has occurred subsequently. The thickening period coincides with the memory of older landholders and explains why it dominates their memories. The density of the vegetation also affects thickening and dieback. Open areas have greater likelihood of thickening up and thickened areas are more susceptible to dieback after drought. Soil structure & death also impact on local patchiness.

Controlling woody plants with fire: Silver-leafed Ironbark - hot fire caused some small trees to die but numbers of <0.2m tall doubled through resprouting of top-killed individuals. Late dry season fires in Kakadu killed 60% of young eucalypt stems but after resprouting 80% survived. + germination after fire. Does more than 1 fire kill trees - impact of 4 fires in 6 years on Ironbarks - losses matched by germination or suckering. Repeated burning may have an effect but only with persistence over longer timeframes. Fire + drought is probably what is required for thinning. Fire most effective on young seedlings. Currant bush cover temporarily reduced by fire but difficult to kill. May be possible to manage wattles by repeated burning before seed have set but likely not to be possible due to lack of fuel.

Fire & pasture: Mainly use to remove rank growth and encourage fresh growth - need to burn
after the first summer rains. Frequency of burning determined largely by rainfall and stocking density. Buffel grass responds rapidly and vigorously to burning.

Fire & wildlife: Fauna have a variable response to fire depending on vegetation structural preferences. *Pseudomys delicatulus* feeds on post-fire flush of seeds & grasses, *P desertor* requires more dense vegetation for protection and is more abundant. A habitat mosaic will result in greatest diversity in long unburnt vegetation.


**Abstract:** The record of eighteenth and nineteenth century explorers' references to Aboriginal fire in Queensland was stratified according to fourteen vegetation types and season of fire. It was demonstrated that references to ‘current’ fire (i.e. flames or smoke) may not represent traditional Aboriginal activity and that many fires were lit to frighten or harm, to protect themselves from, or to signal to kinfolk the presence of the European intruders. Because of this interpretational difficulty the records to ‘current’ fire were treated separately from ‘past’ fire (i.e. burnt ground). The data were analysed as the number of observations per 100 km spent in each vegetation type for any one season to compensate for bias created by differing amounts of travel. The record suggests highest frequency of burning in grassland around the Gulf of Carpentaria, relatively high fire frequency of most coastal and subcoastal vegetation types and relatively infrequent burning of inland Queensland. The analysis indicates a propensity for winter and autumn fire relative to spring and summer fire in all vegetation types combined and in most individual vegetation types.

**Notes:** Examination of the explorer’s record in Queensland provided considerable information about relative fire frequency between different vegetation types and seasonal burning patterns. It has demonstrated that: Aboriginal burning was prevalent in most coastal and subcoastal open vegetation types; Aboriginal burning was relatively infrequent in inland vegetation types; For most vegetation types fire frequency was lowest in summer and was relatively low in spring. The journals used in this study clearly demonstrate that many fires were lit in reaction to the presence of the intruders and such burning was not part of traditional Aboriginal activity. In light of this finding it is stressed that historical records to Aboriginal fire can only be used with prudence.


**Abstract:** Models to calibrate tree and shrub cover assessed from aerial photography with field measurements were developed for a range of vegetation types in north-western Australia. The models verify previous studies indicating that woody cover can be successfully determined from aerial photography. The calibration models were applied to estimates of
woody vegetation cover determined for 279 randomly located sample areas in the Ord–Victoria Rivers region using aerial photography from 1948 to 1950 and 1988 to 1997. Overstorey cover increased from a regional average of 11.5% to 13.5% and understorey cover increased from 1.3% to 2.0%. Downs, Limestone Hills and Alluvia land-types showed the most substantial increases in overstorey cover while overstorey cover in the Limestone plains land-type decreased. Relatively open structured vegetation is most susceptible to thickening. Rainfall records reveal an extreme multi-year rainfall deficit in the study area in the 1930s and relatively wet times in the 1970s and 1980s. Interpretation of a limited set of aerial photographs taken between 1964 and 1972 suggests that most of the increases in cover have occurred since this time. The study highlights the possibility that the average trend of vegetation thickening represents recovery during the relatively wet times after the 1970s. There was no relationship between structural change and a grazing intensity surrogate (distance of sample points to stock watering-points). However, the causes of structural change are undoubtedly multi-factored and the relative contributions of climate, fire and grazing vary for different landscapes and tree species.


Abstract: Fifteen references to vegetation structure from the historical land survey record for the eastern Darling Downs were calibrated with historical photographs to determine the use of the surveyors' structural terminology (Open: 'open', 'light'; Dense: 'heavy', 'thick', 'dense'). Sites with less than 40% canopy cover were only described by terms included within the Open category, and sites with greater than 50% canopy cover were only described by terms included within the Dense category. These results provide calibrations of the surveyors' structural terminology indicating terms were unambiguously applied outside the 40-50% canopy cover range. The use of corner tree distances as an absolute measure of vegetation density is warned against because corner trees had to meet certain criteria and were not necessarily the nearest tree to any corner. However, the distance from allotment corners to "corner trees" provided a measure of the relative use of the surveyor's structural epithets and is consistent with standard application among their fraternity. Survey records dating from 1864-1910 were compared with the structure of existing remnants (projective crown cover measured from recent 1:25,000 aerial photography) to assess changes in vegetation structure. The analysis suggests that 88% of the 34 sites included in the analysis have not changed from the broad structural category that was assigned by the surveyors. Using the assumptions developed by this study, two sites were assessed as having thickened substantially. These results suggest that only minor vegetation thickening has occurred in the Darling Downs since the early land surveys. This conclusion is supported by direct comparison of the historical photographs with existing remnants. Indicating that only one site out of 17 has thickened substantially.

Notes: Questions the general assumption that there has been a general thickening of
woodlands in post European times and cites various studies that have supported this contention. Significantly, papers assessing western NSW such as Oxley (1987) and Pickard’s assessment of survey plans on Moomba Station, were not able to find clear conclusions re direction of structural change in the last 100 years. The existing historical evidence for the Darling Downs does not support an extensive and substantial trend towards increasing density in eucalypt woodland during the period of European history.


Abstract: The growing concerns of the wider community for bio-diversity, ecological maintenance and sustainable long term productivity of Australia's rangelands has focussed attention on land management practices in the semi-arid and arid areas. Where conventional farming paradigms concentrated on farming practices and methods, the paradigms of sustainability rest heavily on changes to farming philosophy for their success. The basic challenges have been well understood for years, and almost all the research has gone into the process of understanding the resource. There is little understanding of the relationship between the ecosystem and either society in general, or the local community. The basic relationship, that between society and the ecosystem, is being overlooked. The social system determines human objectives and the ecosystem presents a range of possibilities through which these objectives are to be realised. Using the work of Ingold, it is argued that technology, ideology and structure are the products of the relationship between society and the ecosystem. The interaction between the ecosystem and the social system then presents a set of possible outcomes that culture attempts to solve. There is a need to shift attention from technology and ideology to examining and understanding the relationship between the social system and the ecosystem if the desired changes, such as the maintenance of biodiversity or sustainability, are to be more than superficial.


Abstract: Contents: Geographic Distribution and Climate; Characteristics (landforms; soils; water supply; vegetation; pasture dynamics and resilience); Utilisation (grazing behaviour; animal diet; animal productivity); Pastoralism (Historical; pastoral industry today); Management Problems (bushfires; woody plants; dry plants; brucellosis & tuberculosis; feral animals; dingoes); Administration; Conservation; Conclusions
Notes: Bushfires: many of the large bushfires originate in the highly flammable hummock grasslands and sweep into the better pastoral country.


Abstract: Trees and shrubs are increasing in parts of central Australia, probably because of changed fire regimes. In other areas, woody plants are predominantly relics, because regeneration is constantly removed by rabbits. Some landscapes remain largely unaltered. Climate, topography and soil all influence woody plant populations but cattle grazing has no detectable impact.

Notes: Study examined open woodlands, mulga, calcareous shrubby grasslands and bluebush shrublands surrounding Alice Springs. Tree and shrub increase has been widely reported in the rangelands of Australia, South Africa and the USA. The central Australian data do not support that shrub increase has been caused by grazing and/or soil erosion and evidence for long term climatic change is equivocal. Pastoralism in the last century has suppressed fire and consequent periodic wildfire has occurred in contrast to the traditional regime. Problem shrubs are susceptible to fire so the primary cause of shrub increase is changed fire regime. The wetter north of central Australia appears to be more susceptible than the south to increases in shrubs, also localised areas of sandier soil run-on wherever water supply and infiltration are enhanced. The drier south experiences fewer rainfall events likely to lead to mass germination events. Regeneration in some southern calcareous landscapes is further disadvantaged by rabbits. The potential for the long term disappearance of the woody resource is high. Rabbits and sheep deplete regeneration but there is no evidence of equivalent damage by cattle in central Australia.


Notes: Over 80% of the 11 western states is rangeland, most of it publicly-owned and on very short-term lease where it is grazed. The push for alternative landuses is strong. There is a real potential for game hunting to be a more productive use of land than grazing on some rangelands. The lack of acceptance of and research into fire as a management tool was notable. Control of unwanted shrubs is a major issue in many areas but it would be misleading to suggest that fire is the single answer. Problems vary from place to place. Sometimes the requirements of a variety of game animals mean different degrees of shrubbiness are important. Sometimes invading fire-enhancing grasses have increased fire frequency to the
extent that fire can eliminate desirable slow-growing shrubs. There has been a strong emphasis on herbicides for shrub control but this is seen as uneconomic and chaining in Texas has also become uneconomic but is still used to keep the land looking good. In the US there is a wide variety of rangelands, opinions, problems and science. Many issues in common with Australia & some that were not. In some cases we can't take US practices on board because our small population base, infertile soils or climatic variability make it impossible.


**Abstract:** Dissatisfaction persists with current approaches to range condition and trend assessment. Sometimes assessed condition does not truly represent the past or the potential range. One of the likely causes is a failure to re-examine and change if necessary the theoretical basis of assessment, in line with the developing understanding of ecological processes. The concept of thresholds of environmental change appears to provide a reasonable alternative in some circumstances to the concepts of gradual retrogression and secondary succession which are currently accepted. I suggest that environmental change will be discontinuous, with thresholds between alternative states. Once a threshold is crossed to a more degraded state the former state cannot be attained without significant management effort, such as prescribed burning, blade ploughing, or herbicide application rather than simple grazing control. Examination of data from extensive monitoring programs, and from a study of grazing impact, as well as more general sources of information, indicates that thresholds of change may be identifiable in arid rangelands. A practical means of monitoring proximity to thresholds is available and, with the aid of multivariate analysis, the effects of spatial variability and season can be separated from those of management. The potential of this approach deserves investigation in a wider variety of environments.

**Notes:** Examples of thresholds: 1. grassland to woodland - this can arise when the grass layer is grazed beyond its capacity to recover quickly and fire suppression enhances the survival of woody plant seedlings; grasses which have been grazed too heavily cannot grow fast enough to compete effectively for moisture in the topsoil; germinating woody plants which are not grazed can outcompete the grasses and subsequently gain access to subsoil water as root systems develop. In periods of high rainfall, topsoil moisture is greater than the grasses can use even when there is grazing and woody seedlings can reach and tap the subsoil moisture. Without fire the conversion to shrubland was essentially permanent. 2. this is reached when erosion outstrips replenishment and soil physical and chemical properties are effectively irreversibly altered e.g. when sandy nutrient rich A horizon is stripped from an impoverished medium of fine textured B horizon. Rainfall is lost in runoff and the environment becomes too xeric for the ready establishment of either grasses or woody plants. In all cases crossing a threshold means the vegetation occupies a new domain and will not revert to its former state without considerable intervention. Other thresholds include the change from palatable perennial grasses to Sclerolaena or unpalatable perennial grasses (e.g. Aristida). Different range sites have differential susceptibilities to change - some grasslands on heavy clay plains
are unlikely to approach either threshold & species composition will shift in response to grazing, fire and season; some savannas may develop woodlands in the absence of deliberate intervention with fire but may be liable to soil erosion.


Abstract: Sustained production in our arid lands is possible, provided the ecological limits are understood.

Over the last 150 years, introduced animals, changed fire regimes and inappropriate government requirements have led to lowered productivity and soil erosion in the pastoral lands.

Now, a number of pastoral land managers are showing that practical experience, coupled with scientific research, points management systems which can prevent further degradation and, in some cases, repair past damage without loss of viability of their enterprise.

We outline some key ecological concepts and some bureaucratic constraints, and we present examples of successful arid zone pastoralists who have maintained or repaired their environment.

Notes: Episodic events: rainfall - the early pastoralists had no experience of similar climates to call on. The rainfall in most of pastoral Australia is 10-20% more variable than the world mean for comparable areas, mean annual rainfall misleading because it is influenced by a few extreme events. Fire is also an episodic event. The important conclusion is that change is episodic. A pulse of high rainfall initiates a sequence of events somewhat out of phase with the rainfall with a consequence that peak animal numbers (domestic and feral) usually occur when the pasture response is fading.

Spatial heterogeneity: Australian arid zone soils are poor in nitrogen and phosphorus but nutrients are not evenly distributed across the soil surface. Shrubs in arid shrublands have an important role in creating micro-environments which enhance soil fertility. Spatial heterogeneity is not restricted to the horizontal plane. Strongly truncated distributions of nutrients and organic matter are common in arid zone profiles so that loss of just a few cms of topsoil can be critical. The potential productivity of the arid zone was rapidly reduced by the loss of fertile patches. Livestock grazed the best pasture until it was worthless and left adjacent poor country alone. Fire is a familiar to central Australian land managers. The watercourses and some of the best woodland country were thick with woody shrubs. From careful beginnings with cool season fires they now burn in summer wildfire conditions and win back some of the most densely shrub infested areas. Recommendations really suggest that property management should be done on small areas and small numbers.

Abstract: We look at the way soil changes have been expressed in the vegetation on calcareous shrubby grasslands. On severely degraded soils, herbage and shrubs were largely restricted to sandy bands, and most herbage was unpalatable. Shrubs were small. Herbage palatability was better on less degraded soils, and the number and size of shrubs were greater. On land rested for 10 years, there was excellent recovery on the sandy bands but not on the intervening stripped surfaces, and there were few large shrubs. Palatable perennial grass appeared for the first time. Thus there is an increase in discrimination amongst landscape units as stability improves, and both vegetation quantity and forage quality are better. Degraded vegetation can recover provided the landscape units remain largely intact; once sandy bands and hummocks lose their structure, a critical threshold is crossed and potential for recovery is low.


Abstract: The short- and long-term post-fire response patterns of small mammals, reptiles and amphibians inhabiting mallee woodlands and heathlands in temperate Australia are reviewed with respect to species' life history parameters in a search for unifying trends. Pyric response patterns of small mammal species are closely tied to their shelter, food and breeding requirements. There is a trend of increased specificity and reduced flexibility in life history traits concomitant with increased impact of fire and later post-fire recolonisation. For reptiles there appears to be a strong relationship between shelter and foraging requirements of species and their abundance in various successional states. The high incidence of burrowing in the mallee/heath amphibian fauna imparts considerable resilience to fire, and most species' abundance and distribution patterns seem more closely linked to moisture regimes than to fire per se.

The high degree of consistency between species' post-fire response patterns and their life history parameters points to the feasibility of developing a model to predict the impact of fire on small vertebrates. Such a model is currently being developed.

Notes: Summary & conclusions: Small ground-dwelling vertebrate species requirements for shelter and to a lesser extent resource based requirements (food etc) have a large bearing on the acute impact of fire and may explain much about the post-fire successional trends. Combustion phase - fire intensity important; shock phase before vegetative cover and structure returns critical for survival and these factors only indirectly determined by fire intensity. Recoloniser mammals have non specialised diets and occupy open habitats. Mid-successional species require denser vegetation and shelter in more flammable refuges and are less general in their diets and a more rigid breeding strategy. Late-successional species show considerable specificity in diet, shelter in flammable refuges and reduced flexibility life history.
strategies.


Abstract: Range improvement practices have been criticised by scientists and the public because of negative impacts on biodiversity. I present a conceptual model based on ecological theory for designing and planning woody plant control to maintain plant and wildlife species richness and diversity. Broad areas of rangeland have been impacted by overgrazing by livestock and attempted brush control in a manner that has resulted in dense woody plant communities that are resistant to natural disturbances such as fire. State-and-transition models of vegetation dynamics predict these biotic assemblages to be temporally stable and not responsive to successional trends; Cultural energy input in the form of woody plant control is required to change the vegetation configuration of these ecosystems. Anthropogenic input conceptualised and designed on the immediate disturbance hypothesis can maximise landscape diversity and may result in a landscape mosaic that supports greater species richness, provides increased forage for livestock and enhances habitat for many wildlife species. A problem with this approach is that continuing inputs are required to maintain the selected landscape architecture. Development models to predict the effects of woody plant control patterns on biodiversity will enable range managers to implement management strategies that maintain or increase plant and vertebrate species richness and diversity.

Notes: Proposes an intermediate disturbance hypothesis on which to base woody plant control. In this species richness and diversity within ecosystems are maintained by natural disturbances within patches in the ecosystem. Level of disturbance is determined by intensity and frequency.


Abstract: With more than 20 million hectares of the Western Division already affected by woody weeds the problem needs to be monitored to determine the future impact of shrub increase on pastoral lands. The large area involved means that effective methods must be used. We are currently mapping occurrence, density and change in cover of woody species using satellite data.

Notes: Using Landsat MSS images - 100m pixels. Ground truthing - from enlarged aerial photos of sub sites also accessible by vehicle. Maps produced from GIS include woody cover for individual dates, change in woody cover through time, emergent woody cover showing the % cover from the contemporary data for pixels which had no cover in the historical image. - 1:500,000 & 1:250,000 scales. Accuracy variable within each image but most within the 10%
tolerance limit although some sites had large errors. The 1973 image coincided with a period of high rainfall so green vegetation flushes would have affected the accuracy of classification. In the Bourke-Cobar area there was a >30% increase over 10 years, largely associated with an increase in the cover of mulga. Moderate increases (11-30%) have occurred further west around Louth and Barnarto. The decreases can be ascribed to wildfires rather than prescribed clearing. Maps have been distributed to landholders.


**Abstract:** Landsat Multispectral Scanner (MSS) digital imagery was used to estimate the distribution, density and change in woody shrub cover over time in western New South Wales. The purpose of the project was to derive maps of woody cover which can be used as a basis for regional planning and property planning. Assessment of woody vegetation cover using satellite imagery enables regions which are more susceptible to shrub encroachment to be targeted for control strategies. Dry season images which had minimal green vegetation were used, because the spectral signatures of scrubby ground cover interfered with the proper classification of woody vegetation. For each region, multidate imagery was classified using a pixel unmixing algorithm to derive data sets which showed woody canopy cover. These data were then rescaled to percentage values using aerial photography sampled throughout each region. A geographic information system (GIS) was used to derive changes in woody cover between both dates and to present the data in map form. Most current woody cover in the study area occurs at less than 20% cover, whilst higher levels (40 to 80%) occur in the eastern parts of the Louth and Barnato regions. At least 20,310 km2 of the 120,000 km2 study area is already affected by woody vegetation cover levels of greater than 40%, which significantly reduces carrying capacity and pastoral productivity. Changes in woody cover over a 10 to 20 year period were varied. Approximately 24% (26,041 km2) was relatively stable, whilst 20% of the Barnato region had moderate decreases (11 to 30%) due to wildfires, and increases of 11 to 30% cover occurred on 'hard red' soils in the east. Emerging woody vegetation of less than 10% cover occurred over 1816 km2 of Sandplains and Stony Lowlands in the Louth and Barnato regions, whilst woody vegetation levels of more than 40% cover occurred in the Barnato region. Considerable 'infilling' of previously unwooded areas was noted for regions which already had high levels of woody cover. A minimal amount of prescribed clearing was apparent from the change data, which suggests that effective control of shrubs is difficult to achieve and that future scenarios will see continued encroachment. The findings suggest that the southern Louth and Barnato regions are most at risk of further shrub encroachment, and that these areas need to be targeted for shrub control. The data provide a quantitative estimate of woody shrub cover which is useful for economic assessments, as well as providing an information base upon which woody shrub management strategies can be developed. Key words: Landsat Multispectral Scanner, remote sensing, geographic information system, change detection, rangeland, monitoring, land cover.

**Abstract:** Fires in mallee vegetation may be fierce but fuel types vary from highly flammable litter-grass-shrub types to scarcely flammable semi-succulent shrub types. Fire protection and suppression measures, such as application of retardants and construction of wide fuel breaks, cause conservation concern. Prescribed burning may greatly assist fire fighters but threaten species such as the malleefowl and a legless lizard with local extinction. Detailed studies of potentially vulnerable species and their distributions in relation to hazards to human life and property should be undertaken. Long-unburnt mallee stands should be protected.

Geographic Information Systems, fire models and expert systems all have value in fire management of mallee lands for nature conservation. The types, quality and densities of data and models, and how they can be checked and expanded, are important issues. Monitoring systems should be part of the management process through which knowledge and prediction are enhanced at minimum cost and with maximum effect.


**Abstract:** Models of ecosystem disturbances have been based on either points or patches. In this study, three types of fire-created patch were distinguished: the unburned 'islands' within a fire area; the patches with individual times-since-fire, those of the first year being the individual fire areas; and, patches with individual intervals between fires. Frequency distributions of patch areas were simulated using two randomly filled square grids (with a probability of 0.5, corresponding to 50% burnt each year) with two levels of aggregation—'none' and 'clumped'. Fires were represented by clusters of filled cells on each single grid; years were represented by a set of similar, independent, grids. Results from the simulations were compared to those from Bradshaw Station in the savanna region of the northern part of the Northern Territory using a decade of Landsat MSS and Landsat TM imagery. Maps of times since fire (years) and intervals between fires (years) were constructed. Proportions of the maps with different times since fire and intervals between fires followed negative exponential curves. All frequency distributions of patch area, irrespective of patch type, were found to be log–log linear when data were logged and 'binned' (i.e. placed in categories). In both the simulations and at Bradshaw Station, the numbers of single cell patches first rose then declined as times since fire increased while the largest fire patches rapidly decreased in size. Between-fire interval patches decreased in size with increasing intervals but small-patch number did not increase as it did for times since fire. Errors in accuracy of Landsat imagery could heighten the apparent conformity between interpreted imagery and the simulations.
Notes: This chapter addresses vascular plants and vertebrate animals. They suggest a series of postulates for the effects of fire regimes in ecosystems, listed below. What are the relative contributions of fires, climate, soils and other landscape features? These factors have been treated in isolation but is this valid? Do they behave as an interacting set with non-linear properties and outcomes, how are important are species interactions? The postulates are a challenge to assess their validity.

1. Fire ecology is the study of the distribution and abundance of biota in relation to their fire-prone environments.
2. The core concept of the fire prone environment is the fire regime
3. The components of a fire regime at one place are not invariable
4. Fire regimes are largely invisible features of landscapes
5. The fire regime is an emergent property of abiotic and biotic factors, not just climate, vegetation, fuels, terrain, ignition sources or herbivore load alone.
6. Abiotic ‘drivers’ of a fire regime occur at a wide variety of temporal and spatial scales
7. Human influences on fire regimes are motivated by value systems
8. Multiple fire regimes can occur in the same climatic or edaphic domain
9. Plant species have measurable characteristics that determine their responses to fire regimes.
10. Some plant species have characteristics that make them ‘fuel species’.
11. Species of plants and animals are adapted to a particular set of fire regimes.
12. Animals and plants can be grouped into functional types with respect to fire regimes.
13. A community of plants consists of species adapted to the same fire regime but with various vulnerabilities to a change in fire regime (i.e., species have overlapping fire regime requirements).
14. Intrinsic variation within a component element of a fire regime can affect biotic outcomes.
15. Temporal patterns of plant-species richness after fire are predictable.
16. Rare or threatened species in an ecosystem may be adapted to the same range of fire regimes as other native Australian species.
17. With change in fire regime, some species may be eliminated quickly but other species will have populations that change only very slowly.
18. Multiple ‘stable’ states (quasi-steady states) of ecosystems’ with different fire regimes are possible in the same area.
19. The assemblage of plant species present in an area is a sub-set of the potential number able to persist there as determined by soils and climate.
20. Fire regimes affect animal habitats to the extent that there is overlap between the influences of fire regime on the ecosystem, on the one hand, and the requirements of animals on the other hand.
21. Abiotic components of habitat (e.g., boulders, rock pavements, soil type as a determinant of burrowing etc.) will interact with the biotic (i.e., vegetation/fire regime driven) components to help determine the persistence of animal species.
22. Some animals may choose between abiotic habitats or fire-affected ones according to opportunity.


**Abstract:** Because of increasing concern over the constancy of intervals between prescribed fires within a vegetation type, we examine various sources of evidence that can be used to determine variation appropriate to the conservation of biodiversity while minimizing the chances of economically destructive fires. Primary juvenile periods of plants (especially of ‘serotinous seeders’) and non-breeding periods of birds (especially poorly dispersed species) suggest extreme lower limits for fire intervals whereas longevity of plant species which usually only reproduce after fire, set the extreme upper limits. Modelling of the behaviour of selected plant and animal species may be used to set ‘optimal’ mean intervals. Historical fire-interval data might seem a useful way to determine the variation about the mean fire-interval but data are scarce and interpretations are controversial. The Weibull distribution and its special case, the negative exponential distribution, have been the most supported in North American studies of unplanned fires. It has been argued that fire-interval distributions, before European settlement at least, were largely the result of large fires during, or following, extreme weather events (dry in forests, wet in the arid zone). Long weather records are most beneficial when they can be related to the areas burned each year. Practical solutions to the question ‘what range of fire intervals should be used at any one site’ may be achieved using highly simplified skewed distributions, constructed on the basis of land-management objectives.

**Notes:** The question is ‘at what intervals should prescribed burning occur?’ Firstly need to acknowledge management aims - in this paper they are the protection of life and property from wildfire and the perpetuation of native biota. A fire interval for fuel reduction could be invariant but this level of regularity may have adverse ecological effect. If there are characteristics of species that indicate limits to possible fire intervals for their existence then these limits provide a starting point for the determination of the frequency distribution of fire intervals in which the species can occur e.g. for obligate seeders, the fire interval needs to be long enough for seedlings to grow and reseed before being burnt again - otherwise they will be eliminated from the community. Less flammable habitats are usually burnt from fires originating in the surrounding more flammable habitat but fires do not always penetrate the flammable habitat. Distribution of habitats in fire shadows and those only penetrated by high intensity fires (eg isolated Acacia scrubs in SE Australia) may be regarded as secondary, being dependant on the primary fire interval distribution of the surrounding landscape. Using fauna in the same way - mallee fowl once common in mallee shrublands of southern
Australia but it is now rare, possibly due to too frequent fire - it seems to only breed 10 years after fire. Other species can be used as indicators. The animal evidence for the establishment of fire interval is open ended - there is often no upper limit to the interval, but a fire-free period prior to the commencement of breeding is an important consideration.

The unprecedented fire in arid and semi-arid Australia in 1974-5 followed widespread, relatively high rainfalls causing a flush of short-lived grasses and resulted in a major filling of Lake Eyre. In central Australia Griffin et al showed that large fires follow relatively wet years and showed that the log of the area burnt / year was correlated with the cumulative rainfall over the previous 2 years. In 1974 the rainfall was so widespread that it gave rise to very widespread fires.

Fire intervals in nature do not have an invariant frequency. The manager has to choose one of 3 options: maintain fire regimes as they were at the time of European settlement, restore ecosystems to pre-settlement ones, apply regimes according to current needs and circumstances. One difficulty is in working out the fire regime used by indigenous people. In the application of contrived fire regimes according to current conditions and circumstances a monitoring system for biodiversity and unplanned fires, linked with a decision support system to assist with the timing of unplanned fires is imperative. There is often a management or legal imperative to burn even in the light of insufficient knowledge. In this scenario the use of life histories should be used as a guide where possible. It is apparent that there is no simple answer to the manager seeking a method to add greater variety to the intervals between prescribed fires but the adoption of a variable system of fire application along with targeted monitoring should assist in the development of a suitable management system.


Notes: Research suggests this widespread phenomenon of woody encroachment has occurred during the past 50-300 years in parts of Africa, South America, North America, and Australia coincident with introductions of exotic species and/or changes in disturbance regimes. Considered a rapid phenomenon encroachment seems irreversible on time scales relevant to ecosystem management. The change in ecosystem structure precipitated by woody encroachment affects hydrology, biochemical cycling, landscape evolution, biodiversity and future landuse options. Also summarises the encroachment in the SW USA, the causes of woody encroachment - internationally the time scale re encroachment is 300-500 years. Most researchers consider woody encroachment to be the result of changes in natural and anthropogenic disturbance regimes rather than shifts in the geographic range of woody species; exogenous causal mechanisms - weather regime and climate change, commercial grazing and fire history.

Future research - the key is to find out whether encroachment represents dynamic oscillation between different cover types or directional change from grasslands from woodlands.

Abstract: Discusses: Geographic distribution; Ecological Characteristics (evolutionary history; component genera; community structure); Response to Environment (climate; dieback); Pastoral Use of the Chenopod Shrublands (industry structure: grazing by domestic stock; impact of grazing stock); Value of Shrubs for Domestic Stock; Management Proscriptions and Prescriptions; Conclusion.


Abstract:
Notes: Wildfire killed 98% white cypress, 83% mulga, 80% narrow leaved hopbush, 48-93% punty bush, 10% of turpentine, budda, yarran, pituri. Small shrubs total kill. Fires of different intensity produced different kill levels. The major effect of on hopbush germination was the wet summer of 1975/6 after which prolific germination occurred on both burnt and unburnt areas. Impact of fire and seasonal conditions need to be separated wrt germination of shrubs. Burning Strategy: burn before 50cm in height - better to get total scorch with a slow light burn and large shrubs become a windbreak. Loss of pasture through burning is small and temporary with little effect to grass species composition and regrowth is rapid.


Abstract: The semi-arid to arid Western Division of New South Wales has suffered significant levels of land degradation due to overstocking by domestic animals and rabbits. Three major forms of land degradation are identified, soil erosion, woody weed growth and pasture quality decline. Restoration techniques developed and applied by the New South Wales Soil Conservation Service are presented and discussed. The successful techniques presented are contour furrowing and waterponding for sheet eroded or scalded areas, fire and blade ploughing for woody weed control and grazing management to reverse pasture decline. The lack of knowledge on pasture species responses to grazing management stimuli is highlighted.

Notes: In land degradation survey of western division 1989 INS estimated to be: severe in 10.3%, moderate 27.3% & minor 29.2% (total approx 70%). Methods of restoration developed by the NSW soil conservation service well developed and respected by land managers, techniques for woody weed control are developed but acceptance by managers - especially fire - is limited. Mechanical control is accepted by cost is prohibitive for the large areas of growth.

Abstract: This paper examines the role of burning as a management tool in western NSW. It explores the historical influences, ecological processes, recent research implications, community attitudes, operational considerations, bush fire brigade inputs and the legal situation. Its main conclusion is that adoption of management burning should significantly increase and current bushfire structures are adequate to accommodate this increase in fire frequency.

Notes: Broad summary of the results of the research and procedures in the area.


Abstract: Changed grazing regimes since European settlement have been widely proposed as the cause of a decline of indigenous perennial grasses in the semi-arid woodlands of eastern Australia. A five year experiment using exclosures examined the effects of grazing on densities of perennial grasses. Short-lived Stipa spp. and Aristida spp. were dominant at most sites. Their densities fluctuated greatly with season and reached over 200 plants/m2 during climatically favourable periods. The long-lived Eragrostis eriopoda occurred at densities that were generally less than 5 plants/m2 and its populations were relatively stable. The response of Enneapogon avenaceus was distinctive. Though its density fluctuated considerably, successive peaks in density were higher and the species increased more in ungrazed areas than in destocked or unfenced areas. The differences between grazed and ungrazed populations became greater with successive peaks in density. Within the short periods that pastoralists are likely to be willing or able to apply such treatments, destocking or even removing all herbivores is unlikely to have a large effect on the density of many palatable perennial grass species. The rate of response to resting pastures will depend on seasonal conditions.

Notes: Grass species vary greatly in responses - from relatively stable to major fluctuations (seasonally & annually). Grazing exclusion did not have the benefits expected possibly because of the permanent loss of species from over grazing.
Notes: Ecosystems that typically constitute rangelands are grasslands, savannas, shrublands and woodlands. The establishment of commercial pastoralism severely weakened most, if not all indigenous societies.

Definition: The term 'range' has been used since the 1400s in England to describe extensive areas of land that were either grassed or wooded - taken by early colonists to the USA where it was associated with 'natural' lands exploited for grazing. Range land is now an international term but there are also many substitute terms e.g. wild lands, outback. Rangelands occur in areas of relatively low rainfall or where winters are long and cold. Vegetation dominated by natural plant communities rather then by sown pastures. Human populations are low density - urbanisation increasing at the margins. Rangelands do not provide a distinct ecosystem - they have been shaped and defined generally by human usage. Rangeland management has been refined with the construction of more reliable water supplies and fences. Additional uses of the rangelands are challenging the traditional definition of rangelands - multiple uses (tourism, ecosystem services, traditional indigenous use of the lands), maintenance of basic resources (sustainability), social and economic processes and interrelationships (rangelands do not exist in isolation from non-rangeland systems).
The study of rangelands since the early 20thC has been driven by decline in productivity and associated soil erosion.

Notes: Contains a series of papers which attempt to obtain and distill the most important concepts, findings and suggestion for future directions that arose from the scientific sessions of the 6th International Rangelands Congress held in Townsville.


Abstract: This chapter describes the climate of central Australia and then examines the relationship between vegetation and fire. The effects of Aboriginal fire management on the vegetation are then discussed in relation to conservation management.

Notes: Rainfall: Incidence and area burnt by wildfires in central Australia is correlated with the cumulative rainfall of the three years prior to the fire. In periods of above average rain, fuel levels become so high and fuel distribution becomes continuous so many fires may occur.
Vegetation and fire: two major plant formations are found in Uluru - arid hummock grasslands
infertile red siliceous sands, plains and dunefields) and Acacia shrublands (on flat country of loams or red earths). Hummock grasslands represent a single fuel type but there are 2 fuel types in acacia shrublands - open woodland plains in which rapid growth of short grasses occurs after rain events and dense mulga shrubland in which herbage growth is suppressed sufficiently to inhibit the spread of fires in all but those periods following exceptionally high rainfall. Mulga trees usually die if burnt and rely on seed germination to recruit. This community appears to have evolved a tolerance to only infrequent fires. A prime concern in managing wildfires in arid Australia is to limit the extensive wildfires that now originate in the hummock grasslands and spread unchecked into the Acacia shrublands. A spatial and temporal mosaic of fire created patches is the regime under which a dynamic system has been maintained for many thousands of years.


Abstract: Discusses: Geographical Distribution and Climate; Characteristics of the Ecosystem (Geology; Soils; water; vegetation; fauna; feral animals); Management and Conservation (Aboriginal land use; pastoralism; wildlife conservation; management with fire); Conclusion

Notes: 22% of the Australian continent - unpredictable climate, nutrient poor soils and frequent fires


Abstract: Results of fire experiments in two important rangeland types in central Australia showed that a winter fire was effective in reducing fuel and was easily controlled. Composition of pasture plants palatable to cattle was either maintained or improved. A summer fire significantly decreased the grass component while increasing the proportion of forbs, particularly unpalatable species. Rainfall, season of burning and reduction of cover appeared to be important factors in controlling the composition of post-fire herbage. There was no important effect of fire on nutrients in either season of burning.

Notes: Plant communities were open woodlands and mulga (grove & intergrove) with grassy ground cover (Aristida, Digitaria, Enneapogon). McArthur meter was unreliable - changes in fuel patchiness can substantially alter fire behaviour. Season of burning can have contrasting effects on the composition of the post-fire herbage but need fires in different years to confirm that seasonal effects are typical. For pasture management and fire control, winter burning is likely to produce an acceptable herbage composition with controllable fires. Summer fires are more difficult to control, may
produce a less desirable post-fire herbage and may increase the soil erosion risk. Improving the accuracy of the fire behaviour models and more deliberate timing of fires in relation to activity phases of plants may offer the opportunity for more precise manipulation of herbage species. Post-fire soil moisture is critical to herbage response and burning periods may be limited to periods of above average rains. The effect of repeated fires, particularly on nutrients, is unknown but the likelihood of frequent fires is small because of the low and erratic rainfall patterns.


Abstract: The effect of a summer fire or a winter fire on tree and shrub populations in two rangeland vegetation types in central Australia was investigated. Changes in population structure of two major species occurred regardless of the season of burn. The decrease in overall density of Acacia aneura, Eremophila gilesii and Cassia spp. was similar for summer and winter fire treatments: greater reduction of E. latrobei followed the summer burn. Higher fire line intensity caused greater mortality in all species but enhanced germination in A. aneura, a potentially ‘weedy’ species. Winter fires appear to be preferable for management of woody plants in the particular vegetation types studied.

Notes: Four major woody species - Acacia aneura, Eremophila gilesii, E. latrobei and Cassia spp. The death of these 4 species was considerable in the absence of fire particularly in the smallest height class but there were further significant reductions in density as well as changes in population structure from burning. Greater intensity in mulga communities not only caused greater mortality but also increased germination and establishment. Opportunities for the manipulation of tree and shrub populations by fire are restricted by seasonal conditions. Winter fires are less intense and less likely to stimulate mass germination of mulga or cassia species. E. gilesii does not appear to require fire for its regulation in central Australia because of its natural mortality rate in dry times.


Abstract: Records of land management practices in central Australia pre- and post-European settlement are examined and it is argued that the introduction of livestock and the European Rabbit and changed fire patterns, have had important effects on some vegetation types. Vegetation changes markedly during periods of high rainfall and drought and it is proposed that livestock and rabbit control during and after these periods and more frequent low intensity burning, are measures which may be needed to maintain or improve landscape stability.
Climate in central Aust - major pluvial events - 1876-1878, 1920-1923, 1973-1978, major droughts 1958-1964 and the more protracted drought of 1925-1938. Rainfall periods sufficient to produce enough fuel to carry extensive wildfires are rare. Three major changes to land management practices followed from European settlement. Domestic livestock were introduced to better watered country, rabbit invaded, Aboriginal burning suppressed. Discusses livestock introduction, land utilised - notes that dependence on natural waters not substantially broken until after 1920 when percussion drills were available but limits still imposed by lack of windmills and engines. Graph of cattle numbers and area of land under lease included. Rabbits: favoured habitat now are soils with high calcareous component, associated sandy soils and salt pan margins. - predominantly chenopod shrublands or woodlands with short grasses and forbs. Loss of Aboriginal population and suppression of Aboriginal burning mosaic by 1920s - big fuel build up from good rains in 1920s (stories of fire from 'Oodnadatta to the Barkly Tablelands') - large areas also burnt in 1973 & 1978. Conclusion: Large scale periodic regeneration is associated with rare high rainfall events. Cattle populations respond to the same pluvial phase but peak populations are delayed and place great pressure on veg during the immediate post pluvial phase when plants are experiencing drought stress. Normal strategies for recovery may get out of hand if the nature and frequency of disturbance change. European land management led to different sequences of vegetation during and immediately following critical periods of high rainfall or drought cf pre-European conditions. Changes in vegetation have not occurred gradually but at discrete periods in time. If the woody plant component of central Australian landscapes and with it the stability and productivity of the landscape is to be maintained or improved then a dramatic reduction of browsing or grazing pressure at critical times after fires and drought is necessary. The need to control grazing and browsing in the recovery period may be as important as in droughts. The return of more frequent low intensity mosaic burning in some areas may be an important means of reducing the impact of high intensity wildfire and reducing the increase of trees and shrubs in some landscapes.


History: Begins by providing a pre-human historical perspective of the evolution of fire survival mechanisms - evolution of savannas with changing climates, lightning strikes etc - fire became a selective force some 20 million years ago. Large fires attributed to aborigines were uncommon in the mulga lands but they did occur but were usually small and scattered. Fire use by aborigines in the mulga lands appears to have been restricted to infrequent burning of many small patches, creating a mosaic of different recovery states. The mosaic presumably provided a range of niches for flora and fauna and allowed many responses in an unpredictable climate. With European settlement burning ceased, the mosaic was lost and fuel accumulation could be dramatic in periods of above average rains eg extensive fires in the 1920s after a wet period. Also 1940s, 1950s & 1970s. Responses to fire: fire incidence and antecedent rainfall are well correlated in central Aust -
pulse & response process, a linked sequence of events. Community responses: Composition and structure of mulga communities is not uniform with grove-intergrove patterning common and even distribution of plants elsewhere. Internal variation in an area increases habitat diversity & the passage and effect of the fire. Burning in winter is suggested as a potentially useful strategy for pasture and woody plant management and for fuel reduction. The management of plant communities with fire must be seen in terms of spatial and temporal patch dynamics rather than individual fires or single patches. Different sized patch burns are arranged in space an over time. A staggered burning program in response to rainfall will increase the stability and diversity of states in the plant community and aid management of wildfires by breaking their passage. Species responses: shrub species with low survival of fire typically rely on fire-promoted germination to ensure their persistence - which depends on time and quantity of rainfall - resprouters rarely regenerate from seed. A knowledge of the general responses of individual species to fire can be useful in deciding whether to burn or not. For woody plant control - the likely reduction in density can be estimated from the relative abundance of the species present.

*Fire, pastoralism and conservation: The main value of fire in mulga lands is to alter the shrub:grass ratio in favour of grass but other uses include the stimulation of herbage growth, reduction of wildfire hazard, creation of fire breaks, maintenance of ecological diversity - opportunities for burning are often fleeting and infrequent and requires an active approach.*


**Notes:** Individual perennial hummocks tend to accumulate biomass after major rainfall events and generally little is lost during the following dry season.


**Abstract:** In the pastorally occupied region of central Australia, annual wildfire occurrences are related to antecedent rainfall, and the seasonal distribution of fires is correlated with the incidence of thunderstorms. Lightning is the main cause of wildfires, and the geographical distribution of thunderstorms is strongly influenced by topography. Wildfires are largest and most frequent in the spinifex fuel habitat in normal or average years, but the plains country fuel habitat carries most wildfires following periods of rainfall substantially above the long-term average. *Acacia* shrublands had the lowest numbers of fires and show poor adaptation to frequent burning. The use of wildfire incidence predictive models, monitoring of thunderstorm movements and prescription burning are suggested as a means of giving greater control over wildfire occurrences and effects in central Australia.
Notes: Maximum incidence of thunderstorms and therefore risk of lightning strike is November which is also a period of low humidity and high temperatures. Widespread wildfires are in inland Australia after periods of above average rainfall, area burnt is best related to 2 years of cumulative antecedent rainfall although 3 years gives a strong relationship also. The response varies with the fuel type.

Fire and fuel habitats: 4 main fuel habitat types and distribution of lightning initiated fires over the 10 year period was largely related to fuel habitats and topography. Highest fire incidence occurred in the central ranges while the plains and Acacia shrublands fuel habitats had lower incidences. Also a high incidence of fire in the western deserts and Simpson desert.

Spinifex fuel habitat had the highest no of fires over the 10 year period with the largest area burnt and the largest mean fire size. Plains country - carried almost as many fires as the spinifex but total area burnt was less than half possibly due to fire control and fuel discontinuity.

Acacia shrublands - Mulga - density of mulga trees varies from scattered or groves, standing biomass in acacia shrublands with an annual grass understorey have been measured as low as 12 kg/ha after below average rainfall; after above average rain biomass levels reached 800 to 1800 kg/ha with leaf litter contributing up to 6000 kg/ha in grove areas following high rainfall periods; with a woollybut understorey standing biomass levels ranged from 100 kg/ha in dry periods to 2600 kg/ha and an additional 2000 kg/ha leaf litter. Interfire period is 30 years or more although 2 fires or more have been recorded following high rainfall. The Acacia shrublands had the lowest incidence of fire of all and the highest incidence of man induced fires.

Hills - highest incidence of lightning caused, in MacDonnell Ranges and the northern Davenport Ranges. Mean fire size was small, most burn out.

Management: plant communities are influenced long term far more by multiple burns than single fire events


Abstract: Strategic patch burning, an Aboriginal practice, is to be reintroduced to Uluru National Park. The management proposal aims to ensure persistent but dynamic and diverse ecosystems while limiting the spread of potential wildfire. Microcomputer analysis, in the field, of vegetation pattern, ecological maturity and fuel states enable immediate management decisions. A fire behaviour model will predict limits of flame spread. Firebreaks and fire fighting equipment are not used.

Notes: Aboriginal burning used to burn patches from a few tussocks to many square kms. Since European settlement aboriginal burning ceased and current wildfire regime is of extensive periodic wildfires following several years of above average rainfall with lightning
being the most common ignition source. Single fires from 30000 sq km, most more than 50 sq km. In 1976 76% of Uluru National Park burnt by a single fire, 37% in 1950. Spatially complex habitats can support richer communities than simpler ones.

Vegetation units were mapped for the entire park and the known fire history related to fire pattern. Fire prone and fire sensitive units were identified and this formed the basis of the management strategy. Two main aims in developing the strategy were to reduce the extent of single event wildfires and to increase habitat diversity ensuring a stable and dynamic ecosystem. The proposal is that over a period of time a mosaic of burnt patches will be built up and this will effectively limit the spread of any wildfire but more importantly will increase the variety of states in a vegetation type enabling the ecosystem to persist through fluctuations in the large scale environmental variables that affect stability, particularly climatic oscillations.


Abstract: Data on the population dynamics of three ‘woody weed’ species *Acacia deanii*, *Cassia nemophila*, *Dodonaea viscosa*, collected over a 12 year period at a disturbed site near Boggabri showed that recruitment generally occurred on an annual basis as soil moisture conditions allowed. Population numbers for *A. deanii* and *C. nemophila* rose dramatically after approximately 4 & 5 years respectively due to maturation of and seedfall from early individuals. *Dodonaea viscosa* showed a slower rate of increase, presumably due to lower levels of seed production. Mortality was highest for all species up to age two while mature individuals persist in the population structure. The results provide further information on the temporal changes of these species' populations over the longer term, with a view to assisting in the refinement of control strategies.

Notes: Recruitment of hopbush & Deanes wattle occurred annually usually during the winter months when presumably soil moisture is greatest. An extra cohort was identified when good rainfall persisted throughout 1983, assisting both germination and seedling survival. Cassia showed less regular recruitment including 3 years with no recruitment. Rapid population expansion occurred for Deanes wattle 4 years after initial recruitment and Cassia after 5 years and continued to increase. Population of hopbush doubled between 4 & 8 years but total numbers low relative to the other 2 species and rate of expansion then decreased. Shrub densities and heights after 135 months are also given.


Abstract: The dynamics of the major mid-storey shrub species in a grazed mulga shrubland community were studied on a series of sites in the arid winter rainfall zone of Western Australia. Of the major species present, *Eremophila leucophylla* decreased with
increasing grazing pressure while *Maireana planifolia* and *Eremophila* sp. declined after a temporary increase. All three species are strongly aggregated around old plant remains and under the canopies of existing trees and tall shrubs. Their aggregation in this microenvironment results from enhanced seedling survival. Common preference for this restricted part of the total space apparently leads to an exclusion type of Interspecific competition and to species populations that are segregated relative to one another. The importance of this microenvironment, and the apparent nature of interspecific competition within it, suggest that a stable state may develop under moderate levels of grazing in this community. The dynamics of the community are unlikely to be explained satisfaction by traditional Clementsian concepts. Rather, they would appear to be more consistent with the concept of alternative stable states. Any beneficial influence of management on community composition, from a pastoral point of view, is thus likely to be limited to discrete opportunities under specific seasonal conditions.


Abstract: Population dynamics of annual forbs and of the grasses *Eragrostis xerophila* and *Monachather paradoxa* were studied in relation to a gradient in range condition within a mulga shrubland community in the arid winter rainfall zone of Western Australia. Frequency of annual forbs appeared to be influenced more by local environmental factors than by grazing. Species which showed definite trends in relation to the range condition gradient were either relatively insensitive to condition changes or occurred at low frequencies and would thus be susceptible to sampling error. The perennial grass *E. xerophila* decreased under heavy grazing but also appeared insensitive to relatively small variations in grazing pressure. Regeneration of this species following drought appears to be a protracted process and may be inhibited by ephemeral growth in the immediate post-drought period. Under severely degraded conditions the semi-perennial *M. paradoxa* displayed a marked reduction in vigour, as reflected in plant size (density/cover ratio), but neither foliar cover nor dry matter production were much affected. The stability of its production under degraded conditions, however, is likely to be reduced relative to sites subjected to more conservative management.

Notes: The observed trends in the frequency of annual forbs in relation to the range condition gradient indicate that such species have little value as indicators of range degradation in the ecosystem studied here. The results are specific to seasonal conditions at the time. Useful indicators could have been revealed under a different climatic regime. On sites in very poor condition pasture spelling in the immediate post-drought period would seem appropriate since reestablishment under such conditions seems less inhibited by ephemeral growth. On areas in good condition even heavy grazing in the immediate post-drought period may not be deleterious to *E xerophila* reestablishment and may even prove beneficial by reducing competition from annuals.

Notes: Introduction: Obvious that an integrated approach must be adopted
Ch 1: Recommended woody weed strategy adopted by the Western & Lower Murray-Darling Total Catchment Management Committees - outline of goals, objectives and actions to implement the plan. Includes a total management programme (knowledge, mapping, education.
Ch 2: Regulations for woody weed control in the western Division - under the Western Lands Act (now superseded).
Ch 3: Integrated woody weed management strategies - 20 million ha of western division estimated to have woody weeds, 10% severely. 62 million ha affected in the USA where the impact of European settlement has been occurring for much longer. Integrated management includes developing a strategy to use the methods in combination. Property planning - draw a property map, identify degree of infestation, evaluate methods of treatment, list priorities, schedule your programme. Total grazing management - sustainable grazing is the major preventative technique to maintain open vegetation.
Ch 4: Grazing management and woody weed control in the semi-arid woodlands - Productive open grasslands can be found next to areas heavily infested with shrubs, on similar types of soil. Woody weed encroachment is not inevitable - it is a symptom of changes associated with grazing management. Approach: management objectives and strategies for individual paddocks, maintain paddock records, manage TGP. Provides a diagrammatic representation of management system which includes a management burn in either Autumn or Spring if required. Notes that after burning the paddock should be spelled until desirable perennial grasses have set seed. Judgements about stocking rates should be based on the levels of pasture utilisation required rather than on animal condition which is a very unreliable indicator.
Ch 5: Blade ploughing for woody weed control - Blade needs to plough well below laterals
Ch 6: Woody weed identification
Ch 7: Mechanical grubbing for woody weed control - machinery & methods, effectiveness, economics. Costs compare favourably with chemical control but have the advantage of protecting desirable shrub and tree species and giving instant results.
Ch 8: Chaining for woody weed control - most widely used of mechanical methods. Shrubs are mostly killed if pulled from the ground - some resprout of bole is broken off at or above ground. Chaining therefore most effective if done in moist conditions. Don’t use for shrubs <2m in height, in dry soil, where erosion is a hazard.
Ch 9: Chemical control of woody weeds in the Western Division - less disruptive to the soil and impact is isolated to the shrub. Use in semi-open areas and on outliers, where there is no other option, on coppicing species and as a follow up to other methods, on small regrowth.
Ch 10: Woody weed management using goats - Have been effectively used to manage some woody weeds and improve pasture production but they are not appropriate for all situations.
Ch 11: Management options - fire: management burns aim to burn only the desired area. A wildfire is usually out of control. Mortality of woody weed species after fire varies - 20-30% for turpentine & buddah, 70-100% for hop bush, punty bush and cypress pine. They are most
easily killed when they are young (approx 100%). Early recognition of encroachment is vital for successful management. Planning for management burning - know what can be achieved including the response to seasonal conditions and grazing management., allow sufficient fuel build up, keep to a manageable size. Management burning can only be successful is sufficient fuel is available to carry the fire and ensure an adequate scorch height.

Ch 12: Taxation and financial incentives relating to woody weed control.
Ch 13: Using contractors for woody weed control work.


Notes: Impediments to the use of fire to control woody weeds: Inability to reduce grazing pressure of the proposed burn area to allow fuel build up; fear of uncontrolled fire; negative views by some in authority' insufficient flexibility within management programme paddock for burning; observations of negative effects on wildlife. Suggested strategy to counter these attitudes: burn in autumn to minimise risk of wildfire; co-ordinate management burning; maintain general low key publicity campaign; training of extension officers and landholders; demonstration burns; high profile publicity/extension campaign; pre & post burn management including TGP and follow up treatments.


Abstract: Shrubs are increasing in density in extensive areas of semi-arid woodland in Queensland and New South Wales, reducing their carrying capacity for stock and increasing the difficulty of sheep management. A case study is reported in which an area exclosed from grazing increased from 6000 to 9000 shrubs/ha in 3 years. Grazing by sheep or goats both reduced the establishment of *Acacia aneura* (mulga) and *Dodonaea viscosa* (broad-leaf hopbush) seedlings. *Cassia* spp. (punt and silver cassia), *Eremophila sturtii* (turpentine), *E. mitchellii* (budda) and *Geijera parviflora* (wilga) were not reduced. Sheep did not affect mature shrubs to any extent. Extremely heavy goat pressure destroyed several problem shrubs, including *Acacia aneura* and *Dodonaea viscosa*, and reduced *Cassia* spp. Mechanical shrub-clearing is often followed by sprouting from the roots of some species. Moderate goat pressure failed to control such sprouts; heavy goat pressure eliminated sprouts from *E. mitchellii* and *G. parviflora* but *E. sturtii* was not eaten, probably because of its higher oil content, and increased to 166% of its preclearing density in two years. Mechanical clearing increased shrub seedling establishment four-fold. Future increases in shrub density may be expected in semi-arid woodland communities and goats do not offer an answer to the problem because they are selective between species and because managerially significant reductions in shrub populations can only be achieved at extremely high stocking pressures. The expense of fencing for such a treatment, the damage to the herb layer and the lack of a
post treatment management, that would prevent the replacement of palatable shrubs by unpalatable ones, makes it an unsuitable technique for extensively grazed properties.

Notes: Widespread fires of 1974-5 only entered margins of Poplar box woodlands with dense shrub growth. Goats introduced to control shrub encroachment. Map of extent of fires and woodland. Found different palatability between the shrub species with mulga & hopbush preferred - grazing did have an impact on these species but wilga & eremophila increased. Goats can also cause the loss of perennial herbage which also suppresses seedling growth.


Abstract: Summary of talk at the seminar 'Management of Shrub Infested Rangelands - Bourke April 1985.
Fire may be used as an ecological management tool to control shrubs. Impact on pasture is not great and fire is not recommended for managing grasses. There are 2 situations where shrubs may need to be reduced by fire - populations of mature shrubs and a proliferation of seedlings. Ideally shrubs should be controlled at the seedling stage - all are susceptible at this stage, low intensity fires are effective, economic losses from mature shrubs are averted, grass growth stimulated by rain is present as fuel, burning opportunities are infrequent and become less frequent as shrubs mature. Where mature shrubs have established, burning management should be related to the species - budda and turpentine should not be priority areas, as little affected by fire but punty, hopbush and mulga will be usefully reduced but a hot fire is necessary. Burnt shrubs produce less seed for many years after a fire - a burn in late spring can destroy the seed on the bushes. Strategic burning in the red country in western NSW will reduce the size of shrubs, density of shrubs and available seed so that the shrub populations will be held in check rather than increasing in dominance. This will be dictated by rainfall and economic conditions. Burning opportunities are scarce (once in 5-20 years) & diminished by mature shrubs. Most of the Cobar Byrock area could not support a burn between 1921 & 1984. Grazing management - shrubs establish more frequently where summer grasses have been grazed out due to moisture competition. If there are perennial grasses don’t flog them. After a wet spring or autumn watch out for shrub seedlings and avoid grazing. If the seedlings survive the following summer burn in the autumn. If there is a problem with mature shrubs minimise grazing in a wet year, burn as early as possible to destroy seeds, as hot as possible. Miss opportunities to burn at your peril. No precise frequency of burn can be prescribed - opportunities to burn and the necessity to do so are related to rainfall.


Abstract: Grazing of wooded grasslands by domestic stock has led to dominance by woody plants, in many parts of the world. In semi—arid grasslands in Australia *Dodonaea*
attenuata is a common, invasive shrub of perennial grasslands on sandy soils. There is evidence that cohorts of *D. attenuata* establish infrequently in vigorous grasslands and more frequently where the perennial grass has been damaged by overgrazing. This study examined the influence of herbaceous growth on mortality of *D. attenuata* seedlings, by growing them in plots with controlled moisture input. The herbaceous layer in the plots was natural, clipped, or killed. Without summer irrigation all the seedlings in the natural grassland died. Seedling survival was inversely related to the amount of herbaceous growth on the other treatments. Summer irrigation maintained *D. attenuata* seedlings and produced a large biomass of perennial grass, which left the seedlings susceptible to grass fires. A water—balance model was run for the experimental site for the 97 yr of climatic records. The soil—moisture patterns associated with the establishment of three known cohorts of *D. attenuata* were identified. The model output was interrogated for similar soil moisture patterns in other years. It was estimated that only six widespread *D. attenuata* establishment events have occurred in 97 yr. In intact grasslands *D. attenuata* rarely establishes densely, and when it does so it is susceptible to grass fires. Modern management has increased establishment frequency by increasing the availability of summer soil moisture by overgrazing the grasslands and has suppressed grass fires. This has changed open grassland to dense shrubland.

**Notes:** In the semi-arid wooded grasslands of eastern Australia, the phenomenon of a diminished herbaceous layer and increased shrub population density was recognised within 30 years of the introduction of domestic stock. Cause ascribed to reduced incidence of fire due to fire prevention or fuel reduction leading to the annexation of light and moisture by an increasing shrub population at the expense of the herbaceous layer. Introduction of fire into management systems was called for but there was also evidence that shrub density might be directly controlled by soil moisture availability and/or competition from the herbaceous layer rather than fire.


**Notes:** The basic assumption, that vegetation was in a steady state at the time of settlement and that changes are ONLY due to grazing are incorrect - shrubs were certainly present and the size of shrubs today indicate they can be long lived. Those shrubs at the time were probably survivors of a previous dense population of shrubs. From current observations the young seedlings die off rapidly in their first 2 years of life and although the death rate slows individuals continue to die off at a steady rate, ultimately leaving a few old individuals. Vegetation is dynamic and it is the extremes that have the greatest effect - droughts and big wets - and would have increased numbers irrespective of European management influence. It is equally certain that station management has had an effect on shrub regeneration and it has been a large effect.

TGP - permanent waters enabled kangaroos to graze year round, in addition to sheep, feral goats and rabbits - in dry times this would have been a many times increase in grass removal -
worst in drought times - causing a change in plant abundance balance - most palatable species disappeared and especially the general loss of vigour of the grass layer. Moderate grazing tends to invigorate most plants but heavy grazing prevents a build up of food reserves - this slows recovery after drought - and causes a reduction in the root system - this increases the number of days/yr when shrubs have competitive advantage over grasses. Ringbarking trees also releases soil moisture which may be used by shrub seedlings so heavy grazing pressure and tree clearance since colonisation has increased the ability of shrubs to invade grasslands.

Fire: Natural grasslands are maintained by fire - Aboriginal burning and American studies have shown that lightning caused fires are surprisingly common in grasslands. There is no doubt that fire was a significant influence on the landscape pre-European settlement but the frequency and character of those fires is subject to debate. Hypothesize that the weather conditions that promoted shrubs also hasten their demise and only areas that missed out on burning that dense shrub populations develop.

In Cobar area where soils have higher soil moisture due to rainfall and soil type and shrubs would establish more frequently. There has been a steady increase in shrub density in these areas temporally set back by the 1921 fire. On the lighter mulga soils small patches expanded in the 1973/74 wet period through wheatfield germination, some was burnt and then stimulated germination which was not burnt off by another fire but in most areas the first fire greatly reduced the numbers of shrubs.


Notes: Plant life histories and life styles: limiting factors - moisture, nutrients, light. Plants of mulga lands - ephemeral grasses & forbs, short-lived perennial grasses & forbs, and long lived shrubs and trees which establish from seed during autumn to spring, avoiding summer.

Competition for resources: Shrub seedlings appear regularly in mulga lands but most do not survive the first summer after germination due to depletion of soil moisture by competing grasses and herbs. In the absence of perennial grasses shrubs survive the first summer without further summer rainfall. Low death rate after survival of first summer. Shrub dynamics is therefore heavily influenced by the vigour of warm season pasture plants - the loss of perennial grasses is due to the maintenance of high stocking rates through low rainfall seasons. The ability to maintain damaging grazing pressure on perennial grasses is enhanced by the presence of drought resistant forage e.g. Mulga i.e. presence of mulga has led to the depletion of perennial grasses and enhances the establishment of unpalatable shrubs.

Influence of Fire: While shrub species vary in sensitivity to fire when adult, mortality is extremely high in all species if burnt before they are 2 years old. Wet summers that ensure the survival of shrub seedlings also produce sufficient fuel to sustain fires. Grass fires not only kill shrub seedlings but also a varying proportion of the adult shrubs, reducing the number of shrub seeds. A single fire could also cause an increase in shrub establishment - mulga and hopbush can be ready to germinate and survive if there are follow up summer rains. - this will also be influenced by the grazing intensity on post fire green pick suppressing grass
competition for moisture. Reduced pasture vigour will reduce fire frequency and reducing its effectiveness, especially in controlling the shrub seedling population. Animal productivity is greatest when only 20-30% of the current growth of perennial grass is grazed by stock. The situation is less clear in areas with predominantly winter rainfall and the perennial grasses are more sensitive to grazing. The second line of defence is to burn ASAP after seedlings survive first summer; third line of defence is also fire after mature shrubs are established but the benefits of this are much reduced and of reduced economic benefit. Practical difficulties: perceived value of dry forage; economic penalties of destocking to burn a large fraction of a single property during the infrequent burning opportunities due to unpredictable rainfall; the delayed benefit from burning young shrubs; the lack of knowledge and skilled labour in controlling prescribed burns; the small paddock size which imposes long lengths of fire break/unit area to protect fences.


**Abstract:** Invasion of grasslands by woody plants following the introduction of domestic stock is a worldwide phenomenon. Burning is frequently recommended as a remedial measure but for a pastoral enterprise it is costly and the frequency of the fires required is of critical economic importance. The size and longevity of the soil seed-bank is an essential part of the response of shrub populations to prescribed fire regimes. In this study the seed-bank of the semi-arid zone shrub *Dodonaea attenuata* in *Eragrostis eriopoda* tussock grassland was examined in relation to harvesting by ants and the burning history of the sites. On unburnt sites, more than 3500 seeds per sq m entered the seed-bank in the summer 1984-85 but sites burnt 5 years previously produced less than one third of that number. Burnt shrubs did not flower for 5 years and no seeds survived in the soil through to 1985. Burning immediately prior to seed ripening destroyed the seed crop but burning after seed-fall stimulated a greater germination in the following spring than on unburnt treatments. Ants rapidly harvested most of the seeds produced and after 20 months the combined effects of ant harvesting and germination had reduced the seed-bank at unburnt sites to 8-21 seeds per sq m and at sites burnt 7 years previously to less than 2 seeds per sq m. Seeds were initially harvested in summer by *Pheidole* spp. of ants for their elaiosome and then discarded in middens outside the entrances to the ant nest. During the subsequent cool season the seeds were taken back into the nest and stored at depths ranging from 2 to 30 cm. It was concluded that ants provided short-range dispersal (<10m) and promoted the contagious distribution of *D. attenuata*, which is advantageous for a fire-susceptible, arid-zone shrub invading a grassland liable to be burnt: seedlings derived from seeds in ant storage chambers near the soil surface and in sparse grass situations caused by competition from shrubs may obtain some survival advantage. Prescribed fire has potential as a management tool for controlling population density of *D. attenuata* because, depending upon season and frequency, it reduces seed rain by killing shrubs, suppresses flowering activity and destroys seed crops on the plant. Under the influence of a regime of regular burning, such as prevailed prior to the European pastoral industry, the limited soil seed-bank would have been a major constraint on *D. attenuata*
populations.


Abstract: This chapter contains a detailed discussion of the ecology and ecological concepts of the vegetation of the rangelands. Begins with brief discussion of climatic influences, especially rainfall. 'The equilibrium of ecosystems where rainfall unreliability is the dominating characteristic is based on adaptability rather than stability'. The Australian rainfall is 10% less reliable than that found at equivalent latitudes on other continents. Chapter discusses: Vegetation - the Influences (Soil moisture, temp, nutrients), Plant Life Forms (ephemerals, perennial herbs, perennial trees & shrubs), Ecosystem Functioning (vegetation dynamics, the concept of equilibrium, tree/shrub/pasture balance), Fire Ecology (the action and significance of burning, fire regime and plant community characteristics, annually burnt communities, regularly burnt communities, irregularly burnt communities), Grazing Ecology (evolutionary influences on rangeland pastures, the pulse and decline of pasture biomass, resilience to grazing), Ecology and Management.

Notes: 'Recognition of the long-lasting influence of extreme environmental events is an essential concept in understanding and managing rangeland vegetation.' Shrub lost in a long dry spell may leave an open herbfield for many years before conditions are favourable for the regeneration of seedlings - plant generation time may be longer than the residency of the observer and may be incorrectly interpreted as an environmental trend rather than a boundary shift within the bounds of the ecosystem. 'Resilience in rangelands is based on the ability of the point of equilibrium to shift widely without leaving a domain of consistent relationships between variables.'

Fire Ecology: Fire regime in Aust rangelands varies from annual (monsoon tropical woodlands), regular at 5-10 year intervals (hummock grasslands) to very irregular and infrequent (arid & semi-arid woodlands, bluebush & saltbush). Unlike grazing fire is non selective and plants are reduced to all having to regenerate at the same time, enabling new species ratios to be established. It also releases nutrients locked in dead plant material and the temporary reduction in the dominance of mature perennial plants enhances seedling establishment and rejuvenates the landscape. Compare this with the view of fire as simply a destructive force. Lists the interactive effects of burning on the environment. A pulse of regrowth follows the first effective rainfall but the survival of this will depend on the available moisture and nutrients. Even extensive fires are patchy and refugia are formed by unburnt patches. Irregularly burnt communities: 'Where burning only occurs irregularly there is greater opportunity for the survival of species which are heat sensitive, non-sprouting and long-lived.' Resilient to single fires but recovery can be long and changes in species composition can last for decades. Any one fire may cause changes but the critical factor is the occurrence of a second fire before the replenishment of seed stores e.g. mulga.

Grazing ecology: These plant communities generally evolved in the absence of the dominant
influence of native grazing herbivores - populations limited by water, dingo & human predation and the unreliable supply of forage over the arid zone. 'The important difference between grazing and fire however, are that grazing animals mainly consume living plant material and are selective between plant species.' Unlike the episodic nature of fire and insect attacks, grazing by stock is a chronic condition.

*Ecology and management:* 'An understanding of the resilience of desired and undesired key species to the combined pressures of fire grazing and variable rainfall is essential to the manipulation of rangeland vegetation.' Grazing during dry times will eventually bare the soil surface, soon after breaking rains will reduce plant food reserves and kill seedlings, grazing of mature growth may have little or no impact. Different plant species may be preferred at each of these times and some plants may avoid grazing stress altogether and therefore increase at the expense of palatable plants. - fire may be an appropriate management tool as it reduces most plants to ground level.


**Notes:** We know of no site which has been burnt where the number of shrubs over the whole area has not been reduced. In certain patches it is possible to show that fire appears to have enhanced the germination of shrub seeds but careful counting usually reveals equal numbers of seedlings in burnt and unburnt areas. It is simply more difficult to see the seedlings in the grass. All species are reduced by fire although some are more resistant than others. Susceptibility of shrubs to fire varies with age. Because most shrubs establish in exceptionally wet years there is usually enough fuel for fires when they are young but it is also difficult to see them at this time and when they can be seen the fuel is gone. Fire management cannot be carried out in the absence of grazing management, including kangaroo control. If the grass is over 2000kg/ha and the wind >7 kph an effective burn is usually achieved.


**Abstract:** Temporal patterns of soil moisture and fire are the primary factors influencing shrub-grass biomass ratios in the semi-arid woodlands of Australia. Under the influence of above average rainfall at critical seasons shrubs establish densely. Because such a rainfall event also produces an unusually large grass biomass, fire becomes a possibility and if it eventuates most young shrubs are killed. Grazing may increase the frequency of shrub establishment by reducing the soil moisture utilised by grass and fire frequency may be reduced where grazing reduces grass vigour. These two factors combine to favour a shrub-dominated vegetation.
Notes: Within the 2.1 million sq km of Acacia wooded grassland in Australia (24% of Aust) there have been great temporal changes in the woody biomass since domestic stock were introduced about 100 years ago. In arid regions the populations of woody plants are reported to wax and wane but in semi-arid eastern Australia there appears to be a trend to increasing dominance by shrubs to the point of extinction of perennial grasses. Increased density and biomass of shrubs is reported for many soil types ranging from clay loams to sands and the depth of soil ranges from deep dunes top skeletal soils so this phenomenon isn't confined to situations where shrubs can exploit moisture at depth which is unavailable to herbs. The value of rain falling in different seasons of the year for plant establishment and growth is summarised. In short, summer rain enhances grass growth but not establishment from seed because of the high temps and rapid drying of the soil; autumn is prime time for the establishment of all plant types and so is winter and spring if followed by a wet summer. The episodic establishment of shrubs - the longest lived element - is the key to understanding the equilibrium and changes in the plant populations. Some favoured micro-environments might support shrub regeneration every few years, widespread establishment has been confined to 1920, 1956, and 1974 which had good autumn rains followed by a wet summer. many sites had no apparent shrub populations before 1974 while other apparently suitable sites are still open grasslands. Death may be due to drought, disease or fire. Role of fire is complex - seedlings of all species are susceptible to fire but adults of some species are extremely resistant to fire (over 99% survival e.g. Budda).

Density of shrub establishment can be so high that if the shrubs survive they eventually outcompete potential fuel plants and protect themselves. In 1975-6 (a wet period) herbage biomass peaked at 1500kg/ha without shrubs and 200kg/ha when shrub-leaf biomass was 1300 kg/ha - at least 900 kg/ha of grass fuel is required to carry a fire in this environment. For grasses the greatly increased density of watering points has allowed pressure grazing to be maintained into droughts for longer than had been possible - domestic stock populations are less responsive to seasonal changes in pasture availability than wildlife because they can't spontaneously migrate and are maintained by artificial feeding during dry periods. Occasional rainfall patterns are so favourable that shrub seedlings establish profusely in vigorous grasslands.

Open grassland depends on fires occurring soon after large scale shrub-seedling establishment events. Fire-reduction of mature shrubs is a contributing factor but would not suffice on its own: the principle effect would be in suppressing the shrubs which established in favoured micro-sites in between 'fire-years'. The influence of grazing is via its effect on the vigour of the field layers, by increasing the frequency of shrub establishment. All large scale shrub establishment events have been accompanied by adequate fuel loads so conclude that it is fire prevention that is the critical factor in the establishment of a shrub dominated vegetation and grazing has been at most a secondary influence.

Mechanism for shrublands to revert to open grassland: There seem to be three points of equilibrium in these systems - open grassland with scattered shrubs, open grassland with patches of dense shrubs and widespread dominance by shrubs (and this appears to be the most stable - or longest lived). A mosaic of shrub patches would allow more frequent fires and greater damage to shrub populations than a continuous shrub layer. In the absence of fire the probability of a change to total dominance by shrubs is proportional
to the resilience of the dominant grass species to grazing. But even in the absence of grazing, shrubs will eventually establish and come to dominate unless burnt.


**Abstract:**
1. Herbaceous biomass was monitored for 9 years in an intact, semi-arid savanna woodland with a 15% canopy cover of *Eucalyptus populnea* trees. Shrubs had largely replaced the perennial grasses since the introduction of domestic stock 100 years previously. The effect of clearing all the woody plants and the shrubs alone was compared with the uncleared control. Grazing was maintained as a sub-treatment for 5 years.
2. During the first major wet period the herbaceous biomass on ungrazed plots, which were either cleared of shrubs or of all woody plants, as a proportion of that of the controls was 4.3 and 6.7 respectively. As the shrubs regrew these values declined, reaching unity and 2.5 respectively after 9 years.
3. Herbaceous biomass was negatively correlated with biomass of tree and shrub leaves. Per unit weight, tree leaves were twice as effective as shrub leaves in reducing herbaceous biomass.
4. Modelling flux of herbaceous biomass on the woody plants-cleared treatment suggested that: (i) no increase would be obtained in any month unless rainfall exceeded 10 days potential evaporation; (ii) herbaceous biomass would accrue at the rate of 0.5 g/sq metre for each mm of monthly rainfall over the above threshold; (iii) herbaceous biomass would decline by 0.1% / month for every mm by which monthly rainfall failed to reach the monthly potential evaporation equivalent.
5. The effects on the herbaceous layer of heavy grazing and complete protection for 5 years were not significantly different after 3 years. This and the rapid shrub regrowth indicates that dominance by shrubs and occasional flushes of ephemeral herbs is a resilient characteristic of these woodlands that has developed from a previous state where trees and perennial herbs were dominant.

**Notes:** Grazing by goats at 0.5 goats / ha - grazing induced reduction in shrub biomass occurred on both the cleared treatments, where shrub biomass was lower, herbaceous growth was greater. Fluctuations in herbaceous biomass indicated that increases only occurred when unusually wet weather prevailed. Average rainfall was not sufficient to induce germination or increase herb biomass. A soil moisture status has to be exceeded to achieve an increase.

The herbaceous layer never achieved sufficient biomass to carry a fire (min 90 g/sq metre required) on the control treatment. A grass fire could probably have been achieved on the 'woody-plants cleared' treatment in late spring 1976, 1978, 1983; the 'shrubs-cleared' treatment only achieved that state in 1976 and with a marginal biomass. Burning this vegetation causes high mortality of young shrubs and if done would have greatly reduced the regenerating shrub biomass.
Suggest that the vegetation in this area has been shifted from one state to another with the new, less productive state more resilient than the other.


Abstract: Describes the semi-arid woodlands of western NSW and Queensland including: Climate; Soil; Vegetation (population dynamics; trees; pasture); Socio-economic Structure (administration; the pastoral industry; animal production); Range Management (vegetation management for grazing; control of grazing pressure; management of mulga; alternatives to fire for shrub control); Socio-Economics of the Pastoral Industry; Feral Animals; Conservation; Conclusion.

Notes: Shrub control and maintenance of a vigorous perennial pasture is the key to good biological management. This will necessitate the use of fire and the permanent avoidance of overgrazing.


Abstract: This article outlines the exploration and settlement of poplar box lands which followed the European occupation of the Australian continent in the mid-19th century, draws attention to the various fragments of historical information on substantial changes in the soils, vegetation and biota, and describes the role of European livestock (sheep, cattle, goats, rabbits) and fire in these changes.

Notes: Outlines the settlement of western NSW & Qld and compiles descriptions of the original vegetation and soil. Large-scale ringbarking and scrub clearing also occurred through this period. The history & impact of bushfires is also described, especially the potential impact on scrub regrowth. Changes to rabbit & kangaroo population is outlined, followed by the impact of all grazers on the ecosystem (TGP). Animal effects on the soil are analysed on limited data but indicate there can be little doubt that there has been a permanent loss of top-soil & nutrients. Conclude that the long term decline in the condition of the poplar box lands was temporarily arrested by higher rainfall in early 1950s. Shrub dynamics: have undoubtedly increased but conclude that grazing period, TGP, rainfall patterns and association with fires need to be assessed.

Abstract: Contents:
Part I Concept and Principles - Ch 1 Management of Rangeland Ecosystems; Ch 2 Management Aims, Objectives and Responsibilities
Part II Management Processes - Ch 3 Land & Water Processes; Ch 4 Vegetation Ecology and Management; Ch 5 Grazing Ecology and Animal Production; Ch 6 Socio-economic Influences on Pastoral Management; Ch 7 Biological Conservation.
Part III Management Practices and Procedures - Ch 8 Range Inventory and Monitoring; Ch 9 Grazing Management; Ch 10 management of Vegetation with Fire; Ch 11 Rangeland Administration; Ch 12 Rehabilitation of Degraded Land
Part IV Rangeland Types - Ch 13 Semi-arid Woodlands; Ch 14 Saltbush and Bluebush; Ch 15 Mallee; Ch 16 Mitchell grasslands; Ch 17 Tropical and sub-tropical Woodlands; Ch 18 Hummock Grasslands; Ch 19 Arid Mulga Woodlands; Ch 20 Central Arid Woodlands; Ch 21 Temperate Rangelands
Part V Stocks and Resources - Ch 22 Distribution and Influences on Rangeland Management


Abstract: 'Rangelands are semi-natural ecosystems which man seeks to obtain a productive output by simply adding domestic stock to a natural landscape. He does not plough or fertilise; the natural plant communities form the basis of his enterprise and the native animals species, although modified remain intermingled with his sheep and cattle. Management is ecological in nature, of low energy input and involving actions that seek to modify, rather than control the natural forces operating on the land. Management is weak in proportion to the dominant climatic forces that control the ecosystem. The well-being of pastoral man depends on the land and its ability to maintain it in a productive condition. Man becomes a part of the ecosystem: living within it, controlled by it and maintaining it as best he can.

The foundation of the ecosystem concept is that all parts of the environment are interrelated. Manage the animals and you affect the plants; manage the plants and the soil will respond; care for the soil and the animals will benefit.

In the rangelands the principle tool managers have at their disposal is the deployment of grazing pressure.'

Limitations to management: soil types, rainfall, market supply and demand, cash flow. Management must consider immediate productivity and survival as well as long-term management for maintaining the resource base.

Notes: The management paradigm described here clearly states the overriding control of climate - particularly rainfall and the consequent soil moisture levels. Water acts as the driving variable of the system.

Figure 1.2: diagrammatic representation of the relative strength of influences on the
managerial decisions of a pastoral property: Climate - controls management decisions which affect ecosystem variables; ecosystem variables include vegetation (forage quality and quantity, weeds, plant births & deaths) and soil (dust storms, gully erosion, sheet erosion, water permeability) and the delayed effects of these factors which then influence animal production and management decisions.

Rainfall does not percolate evenly into the soil but is redistributed - varies in scale from the shedding of water into drainage lines to impedance of water by grass tussocks, enhancing the moisture environment for some plants and producing groves or banded vegetation. Nutrients are coupled to water flow. Rainfall is distributed unevenly in space and time and rainfall predictability is extremely low.


Abstract: Attitudes to the Australian rangelands have changed markedly over the last 20 years in response to a variety of changes in societal attitudes to the environment in general and changes in national and international scientific knowledge on the nature of the rangeland ecosystem. The paper provides a brief review of those changing attitudes, seen in the context of the sociologist Cohen's four environmental orientations: instrumental, territorial, sentimental and symbolic. Evidence of each is provided and it is argued that future management of the rangelands will need to take cognisance of the variety of views of the nature and role of the rangelands which those orientations encompass.


Abstract: Concern about the risk of harmful human-induced climate change has resulted in international efforts to reduce greenhouse gas emissions to the atmosphere. We review the international and national context for consideration of greenhouse abatement in native vegetation management and discuss potential options in Queensland. Queensland has large areas of productive or potentially productive land with native woody vegetation cover with approximately 76 million ha with woody cover remaining in 1991. High rates of tree clearing, predominantly to increase pasture productivity, continued throughout the 1990s with an average 345,000 ha/a estimated to have been cleared, including non-remnant (woody regrowth) as well as remnant vegetation. Estimates of greenhouse gas emissions associated with land clearing currently have a high uncertainty but clearing was reported to contribute a
significant proportion of Australia's total greenhouse gas emissions from 1990 (21%) to 1999 (13%). In Queensland, greenhouse emissions from land clearing were estimated to have been 54.5 Mt CO2-e in 1999. Management of native vegetation for timber harvesting and the proliferation of woody vegetation (vegetation thickening) in the grazed woodlands also represent large carbon fluxes. Forestry (plantations and native forests) in Queensland was reported to be a 4.4 Mt CO2-e sink in 1999 but there are a lack of comprehensive data on timber harvesting in private hardwood forests. Vegetation thickening is reported for large areas of the c. 60 million ha grazed woodlands in Queensland. The magnitude of the carbon sink in 27 million ha grazed eucalypt woodlands has been estimated to be 66 Mt CO2-e/a but this sink is not currently included in Australia's inventory of anthropogenic greenhouse emissions.

Improved understanding of the function and dynamics of natural and managed ecosystems is required to support management of native vegetation to preserve and enhance carbon stocks for greenhouse benefits while meeting objectives of sustainable and productive management and biodiversity protection.

Notes: This paper provides a detailed background to the interrelationship between clearing and greenhouse gas production in Qld. It covers the international response to climate change (IPCC, UN Framework, Kyoto protocol), greenhouse accounting for land use change and forestry, land cover and carbon stocks in native vegetation in Qld, greenhouse accounting (land clearing, clearing rate, biomass, clearing practices and delayed emissions, regrowth, soil carbon, managed native forests, CO2 concentration, climate, grazing, fire), Kyoto Protocol accounting for land use, land use change and forestry, managing carbon stocks in Qld's rangelands (options for management of natural resources for greenhouse benefits - reduced land clearing, enhanced soil carbon stocks, afforestation and reforestation). Concludes that Management to increase carbon stocks in the terrestrial biosphere has the potential to offer cost-effective, short term greenhouse abatement options to enable time for the development of technologies to reduce total fossil fuel emission. With international agreements there will be increasing pressure on landholders to reduce rates of tree clearing to increase the carbon stocks in the landscape in addition to biodiversity protection and ameliorating land degradation.


Abstract: Vegetation on arid rangelands of the southwestern United States in the last 100 years are described. Reasons and solutions to the problems resulting from these changes are discussed. Shrubs have increased dramatically with a corresponding reduction in herbaceous plants. Encroachment of woody plants into previously shrubless areas is closely correlated with man's activities combined with drought. Man has been a disturber of natural systems and
his ability to create disturbances has increased as technology has increased. Increased use of arid rangelands of the southwestern United States is possible with intensive practices such as brush control, revegetation where needed and improved grazing management.

Change, an inherent characteristic of ecosystems, is a recognised feature of vegetation of the arid and semi-arid portions of SW USA. Parts of Arizona, New Mexico and Texas are included in this review. Territorial surveys in the 19thC and terrestrial photography in the 19thC and early 20thC have been used to establish a base for vegetation conditions and then for recording variations to this base. All evidence indicates a dramatic shift from a high proportion of grassy vegetation to one dominated by shrubs in the last 50-100 years. This paper describes these changes and attempts to discuss the reasons and solutions to problems resulting from these changes.

**Notes:** Shrubs were slowly invading grasslands before man's influence - increased human activity produced rapid shrub increase. Studies indicate that the current Arroyo cutting cycle and initiation of dramatic vegetation changes in the SW began in the 1890s, coinciding with a drying/warming trend (1875-90) and heavy livestock use. Rangelands in New Mexico and southern Arizona were seriously depleted by prolonged overstocking before 1900. Woody plants were present under pristine conditions but rarely migrated from specific sites onto the grasslands. They now form almost continuous cover over large parts of this area. Rapid increase of shrubs from 1858 to 1963 on 58,500 ha: Honey mesquite - 4.8 to 50.3 % area; creosote bush - 0.4 to 14.2%; tarbush - 0.4 to 8.6%. The Arizona chaparral was more open prior to livestock grazing in the 1870s than it is today - heavy grazing depleted perennial grasses. Introduced annual grasses and forbs replaced the native perennial grasses that grew in openings between the shrubs and as understorey plants. Suppression of fires has resulted in thicker stands of shrubs in recent years. Chaparral is maintained by instability such as flood, fire or erosion. Increasing site stability allows chaparral to be replaced by woodland, savanna or grassland depending on the degree of stability, frequency of fire and location.

Encroachment of woody plants into previously shrubless areas is closely correlated with the intensification of the activities of modern man. 'People pressure' has complemented fluctuations in climate and local weather allowing increases in cover of shrubs. Before the influence of white man the mobility of native grazers naturally deferred grasslands during dry periods. Today fences restrict the movements of grazing mammals.

Influences of man in changing plant cover: restriction or elimination of naturally occurring fires where fuel is adequate - fires were not an important factor in reduction of shrubs in arid grasslands because there was insufficient fuel, where there is sufficient fuel fires will kill some plants; attempts to cultivate unsuitable land; Continual grazing pressure on grasslands by an increase in the number of grazers and timing of grazing use; the increased mobility of man and domesticated animals resulted in greater seed dispersal - seeds of unwanted shrubs have been dispersed and simply await the right conditions for germination.

Rangelands are a biological system and a holistic approach to its management is necessary - weather + soils + plants (native and introduced) + animals (native and introduced). Pristine conditions should not be confused with site potential and secondary succession is very slow or non existent on arid rangelands of SW US.

Notes: Ten pastoral families from the mulga lands of NSW & Qld have described the types and outcomes of their grazing management practices including: use of fire to control woody weeds; stocking rates and grazing management strategies; agistment and sale of livestock; livestock handling & performance; improvement of pasture composition and productivity; advantages of livestock mixes; use of mulga browse; management of goats and kangaroos. Graziers believe there is no one ‘right way’ to manages mulga country. Each property is unique in structure and land types and each manager has their own personal style which they continually adjust to suit the prevailing climate and economic conditions. The key is to continually read the country and adapt management practices to suit ever-changing conditions.

Mulgalands: Good evidence that prior to settlement most of the mulga country was open woodlands. Now mulga densities often exceed 5000 stems/ha or one every 2 sq m. Hopbush & turpentine can exceed 15000 stems per ha. In the mulga environment spatial redistribution of water and nutrients is strongly influenced by terrain & vegetation (mulga groves, litter, perennial grasses & logs). Rainfall is rapidly redistributed as run-off from sparsely vegetated areas unable to absorb or obstruct water. Vegetation patches become enriched & productive over time. Patterned or groved mulga - moderate infiltration in the intergove, high infiltration in the grove.

Case Studies:
- **Guestling, Charleville**: The gradual thinning of areas infested with woody weeds has arrested a decline in carrying capacity as pastures improved; Good returns on goat meat, the availability of goats and their possible role in woody weed management encouraged diversification into goats; Kangaroos are managed by a licensed harvester when congregating; Burning to control woody weeds is usually done in spring and has had good results in control of green turkey bush, sandalwood and poplar box suckers.
- **Bullaroon, Bourke**: A mix of 3 livestock enterprises (cattle, goat & sheep) gives more options and gets more out of the country without over exploiting it; Mulga drought proofs a property as it supports livestock throughout the drought; Mulga should be fed to livestock early in the drought before pasture and animals have lost too much condition; cattle are used to keep mulga within browsing height of sheep and goats.
- **Mt Mulyah, Louth**: The country is moderately stocked, even during favourable seasons to allow feed to build up; Surplus non-breeding stock are sold with the onset of drought to maximise feed reserves for the breeders; Blade ploughing followed by fire provided good control of woody weeds (I can think of times when we could have had a huge blaze & killed a lot of the scrub but were too frightened about the possibility of the fire getting away to light up & the possibility of litigation is a deterrent - burning occurred 1984-1986 wet period. My view on fire changed with the general acceptance that hazard burning was a legitimate tool in wildfire control.); it is important not to make hard and fast management rules but to assess each situation as it arises.
- **Alice Downs, near Charleville**: Cattle and goats introduced to the original sheep run provide benefits of diversification and co-grazing; goats need to be run at reasonable stocking rates for good reproduction and returns; with a conservative stocking strategy the paddock grazing
pressure is controlled using water closure, fencing to land types and destocking after periods of good rainfall; dung sampling of cattle is used to provide a greater understanding of pasture protein and digestibility. Tactical grazing has prevented the regeneration of mulga in some areas. Plans to burn to control woody weeds, rank grass & timber on the ground.

**Turn, near Thargomindah** - Short term rest applied to paddock pairs after periods of beneficial rain has increased the amount of available feed; a seasonal rest of about 4 months is used to benefit specific pasture plants; long term rest of an area of 12000 ha aims to maintain a desirable pasture mix and a sufficient amount of browse; a flexible management approach responsive to circumstances is important.

**Korindina, Wanaaring** - Where there is a fair bit of woody weed (hopbush, punty bush, etc) coarser grasses still grow but sweeter grasses are no longer present. Coarse grass will grow underneath woody weed except for harlequin fuschia bush. The control of fire has obviously contributed to the spread of woody weeds. Softer sandy country seems to respond better than the hard red country. If you have a fire go through you are more likely to have seed come through and germinate on the sandy soil. In the harder country a lot of seed sits on the surface and doesn't survive.

**Bulgoo, Cobar** - Planned grazing management introduced to encourage growth & productivity of perennial grasses - one key being the resting of each paddock after it has been grazed; some pasture cover is always left (as standing veg & litter) to trap rainfall on the ground; Kangaroos are not a problem if tall feed is around the property. We think the solution to controlling woody weeds is to pull the country (chain it) leave it then go back in a drought year and burn small patches - burn the timber on the ground, resprouting shrubs and the grass fuel underneath. We use 2 or 3 people with a drip torch in small areas. we get 90% kill even with turpentine and don't burn the perennial grasses inbetween the shrub patches. Control of seedlings is helped by animal impact and chemical treatment of those plants that are not completely burnt.

**Woodstock, Cunnamulla** - Quality pastures & good management can result in an extra 10-20% lambing rate; rest for 3-8 weeks after rain increases pasture production by 50-80%; a 10% reduction in livestock numbers had no negative effect on total wool production.

**Westmere, Louth** - By stocking conservatively you can produce more wool from fewer animals; feeding mulga for drought feed is only a short term option.

**Armoobilla, near Charleville** - understocking after good rain has allowed the country to grass up which now means it is better able to respond to small amounts of rain; control of woody weeds in selected areas can also increase the productivity over time, control by pulling. Better management of mulga can contribute to the recovery of native perennial grasses across the entire paddock.

**Conclusions, common themes:** Managing vegetation with fire - fire was a common feature for keeping shrubs in check and maintaining open woodlands. 'Burning is useful in clearing pulled timber for better access, controlling regrowth, clearing old grass to allow for fresh new growth and in providing a seedbed for the planting of improved grasses. However fire can have a damaging effect if not managed correctly. For example, a fire that is too hot may result in scalding of the soil surface and stocking too soon after burning can damage pastures and lead to erosion.

Abstract: Of the 25 species of shrubs common in poplar box lands, 17 are considered to have reached the status of being a "woody weed" in New South Wales and/or Queensland. Thickening up of scrub in pastoral areas appears to have been episodic after periods of above-average rainfall. Germination of seed may occur at most times of the year if soil moisture is high. Fire promotes germination of species with hard seeds (some Acacia, Cassia, Dodonaea spp.). Increased shrub density usually follows soil disturbance if seed is present, and once established, the individuals of most species appear to be long-lived. Productivity of shrub communities is commensurate with rainfall. The species are well adapted to tolerate drought and they retain leaves under extreme water stress. Most species flower and set seed each year in the spring and summer period but in more arid parts of poplar box lands some species reproduce opportunistically after good rainfall. In favourable conditions most species produce copious quantities of seed. Dormancy is common in seed recently shed and loss of dormancy may occur within months or up to 3 years after seed shed. All species are subject to invertebrate and vertebrate predation and death of individuals or whole populations may sometimes result. A few species are moderately palatable to domestic livestock and native herbivores; the majority are rarely eaten even by starving animals. The regenerative ability of shrubs following fire or grazing differs amongst species and is affected by shrub size.

Notes: Provides list of invasive shrubs and level of problem in NSW & Qld, discusses limits to distribution. Details of germination requirements - water & temp + effects of soil disturbance, fire - follow up rains needed for establishment. Notes that there are some less spectacular germination events between major events which lead to insidious increase. Also discusses longevity, growth patterns, water stress, palatability and regeneration ability after fire or mechanical clearing. Provides a table of survival characteristics which very significantly between species. Fire can lead to a change in species dominance rather than removal of the problem.


Abstract: Summary of talk at the seminar 'Management of Shrub Infested Rangelands - Bourke April 1985.
Grazing and wildfire control has reduced fire frequency - causing shrub increase and grass decrease; all plants adapted to survive periodic fires; mortality of established shrubs varies greatly depending on the species - turpentine and budda readily coppice after fire - 15-20% die, mulga and narrow leaf hopbush have low resistance to fire (75-95% die); seasonality and intensity of fire has less effect than species on shrub mortality; recently established seedlings of all shrub species are killed by fire but seed of some shrub species (punty bush and narrow-
leafed hopbush may have germination promoted by fire; grasses generally resistant to fire; fire does not damage pasture - rather it promotes it; rest burnt areas from grazing until the perennial grasses have seeded again.


Notes: After an experimental fire in mulga woodland, pulse size and duration were much greater in burnt treatments than in unburnt controls. Fire also temporarily shifted the species composition of the plant growth pulse. In the autumn burnt treatment, annual forbs dominated the pulse in the next and several following years while annual forbs were a lower proportion of the biomass in unburnt areas.


Abstract: 1. In a fire experiment involving different intensities and seasons over a 2-year period, fire enhanced the germination of two of the seven principal shrub species in a semi-arid shrub-invaded woodland site in eastern Australia. 2. The level of shrub recruitment increase slightly or not at all with higher fire-line intensities. 3. The mortality rate of a fire-enhanced cohort of Cassia eremophila was density-dependant and decreased exponentially over time. 4. The pattern of shrub recruitment across the landscape was strongly influenced by the fire-line intensity; the proportion of 9 sq m quadrats containing seedlings increased linearly with fire-line intensity from 0% for some controls to 100% when intensity reached c. 3000 kW / m depending on the season of the fire. 5. Spring, summer and autumn fires enhanced germination more than winter fires, with the amount and time of post-fire rainfall being influential in governing the proportion of shrub seedlings that established. 6. The density and frequency of fire-recruited shrubs can be manipulated by selecting the season of, and environmental conditions for, prescribed burns.


Abstract: Summary: Plant water relations and shoot growth rate of shrubs resprouting after fire or unburnt were measured in a semi-arid poplar box (Eucalyptus populnea) shrub woodland of eastern Australia. In vegetation unburnt for about 60 years, the dawn xylem water potential of the dominant shrub species was about -1.0 MPa when the soil was wet and
-8.0 MPa when the soil was very dry. At any one time, the dominant shrub species, *Eremophila mitchellii*, *E. sturtii*, *Geijera parviflora* and *Cassia nemophila* were similar in xylem water potential but *Acacia aneura* and *Dodonaea viscosa* were considerably higher than this group when the soil was moist and lower when the soil was dry. The dominant tree species, *Eucalyptus populnea* and *E. intertexta*, appeared to have access to additional water beneath the hardpan which is located 60-80 cm below the surface. When shrubs were under extreme water stress (-8.0 MPa), the trees had a potential of -3 to -3.6 MPa. Following a fire, both xylem potential and leaf stomatal conductance of resprouting shrubs were higher for about 5 years than comparable-aged unburnt vegetation, with relative differences in xylem potential increasing with drought stress. Elongation rate of resprouts was positively linked to pre-fire shrub height in 3 of 4 species. However, shrubs resprouting after high intensity fires has substantially higher rates of shoot elongation than after low intensity fires which were in turn higher than for foliar expansion of unburnt shrubs. It is concluded that the growth rate of resprouting shrubs is primarily determined by physiological/morphological factors associated with plant size but is also assisted by greater availability of water and possibly nutrients for a period after fire.


**Abstract:** The *Acacia* communities of arid and semi-arid Australia are subject to recurrent fire. Fire occurrence is strongly dependant on herbaceous plants that become dominant after irregular high rainfall periods and therefore fire frequency is low (e.g. 30-50 years). The exception is where *Acacia* species occur over hummock grasses; steady growth of the grasses predisposes the community to fire once litter exceeds a critical level. Under pastoral management of these lands the frequency and extent of fires have generally declined. However ignition by humans in parts of Western Australia and near settlements has locally increased fire frequency. Fire as a consumer of living and dead plant material exposes landscapes to erosive forces and if heavy grazing occurs the effects may be compounded. The landscape function model by Ludwig et al. (1997) is used to explore how the fire (and grazing) regime may affect landscape function attributes and linked biodiversity values. Implications of these relationships on prospective assessment and monitoring procedures are discussed.

**Notes:** In this paper the landscape function framework is used to link the disturbance of fire with change in landscape function and biodiversity.

*Fire regimes:* The distribution and amounts of rainfall, vegetation patterns in the landscape and the grazing of domestic livestock shape the fire regimes in Acacia landscapes - plus human ignition and fire control. In general the frequency of fires in the Acacia plant communities is very low - 10-50 years. It is not necessarily associated with a particular season but chance of fire is greatest September to March.

*The Acacia landscape:* Landscapes in Acacia communities comprise resource rich units or fertile
patches separated by more open, resource-poor zones. Patches occur at a range of scales: individual plants, clumps of trees, shrubs and grasses, and zones of vegetation within landscapes.

Feedback effects of fire on landscape function have not been systematically measured but fire affects landscape function by recycling plant materials and the density and size of patches. Patch size in turn affects surface transfer of water and nutrients. The net result of fire on landscape function can be a dramatically enhanced pulse of plant growth when triggered by subsequent rainfall - pulse size and duration shown to be greater in burnt treatments than controls.

After fire damage most tree species are resprouters except some such as cypress species. Most perennial grasses also survive fire damage and tiller again but some suffer high mortality. The death of perennial plants following fire damage creates new spaces within landscapes.

_Fire-grazing interactions:_ Grazing, especially by large herbivores is a strong vector for change in these lands but unlike fire is persistent - fire is episodic. Fire + grazing is a major threatening process for many species in acacia communities. These two disturbances, especially during drought are likely to have a dramatic and long lasting impact on biological diversity.

Together these impacts can change the function of the landscape so that scarce resources of water and nutrients are not retained in the landscape. The onset of dysfunction reduces the chance of suitable edaphic and habitat conditions for recruitment and survival of many plant species and persistence of some populations may be severely threatened.


**Abstract:** Fire is a natural environmental stress in the arid zone (which in this paper includes the semi-arid zone) as it is in most regions of Australia. It differs from other environmental stresses in that it occurs infrequently (5-50 years or longer between fires) for only a very short period (flame duration in grass fires is about 5 seconds), is self propagating, and may destroy all above ground parts of plants. Although fire occurs infrequently, it has been recognised that it has considerable evolutionary significance and that fire prone communities need to be burnt at a certain frequency, intensity and season (the fire ‘regime’) to maintain ecosystem stability and species richness.

Following the pluvial period of 1973/74, in which there was a widespread growth of ephemerals as well as perennial grasses, extensive wildfires occurred in the summer of 1974/75, burning an estimated 120 million hectares of the arid zone. Parts of all major plant communities were burnt. The effects of burning on some shrub species were apparent soon after these wildfires and long term studies on effects on selected communities were commenced in western NSW and central Australia.

The objective of this paper is to identify those adaptive traits that enable populations of shrub species to persist after being burnt and to discuss the evolution of these traits against a background of a long fire history for the arid zone.
Notes: Aboriginal use of fire: used in daily existence for signalling, hunting, driving out game, promoting a green flush of grass to attract game, increasing abundance of species for food that require fire for germination, clearing land, fun, and warmth. Whatever the fire regime that was introduced by aboriginal people, the fire regime was at least altered to increased frequency, lower intensity and carried out in most seasons. Large wildfires were probably less prevalent - these changes may explain changes in botanical composition over the last 40,000 years.

Since European occupation wildfires were controlled as quickly as possible. Overgrazing (TGP) has also greatly reduced the fire frequency. Wildfires when they do occur now probably mimic pre-Aboriginal times. Suggests shrub woodlands burnt every 10-20 years pre-European, now >100 years if invaded by woody shrubs. Communities containing hummock grasses may be burnt at the highest frequency.

Traits facilitating survival of established shrubs: resprouting or coppicing - survive fire damage. Wide variation between species and within genera; fire avoidance - high leaf salt levels and suppression of grass growth. Traits facilitating reproduction from seed: fire-enhanced flowering - uncommon; early reproductive maturity - *Senna, Dodonaea* can flower and set seed within 3 years of germinating, *Eremophila* spp are slower; heavy seed production; long lived seed store - species with high numbers of seeds in the soil (Mulga, *Senna nemophila, Dodonaea viscosa, Eremophila gilesii*) have low resprouting ability and depend on germination and seedling establishment to persist after fire. *Eremophila mitchellii* and *E. sturtii* have low seed numbers and high resprouting ability; fire-promotes germination - *Acacia, Senna, Dodonaea*. Obligate seed regeneration is absent from the arid zone which may be related to the unreliable rainfall.

Suggest that when fire frequency is high (5-10 years) the most successful strategy would be for shrubs to resprout because there would not be enough time for seedlings to mature - with longer fire intervals regeneration from seed might be more successful.


Abstract: The case for using fire to control shrubs rests on the idea that widespread shrub establishment events and wildfires occurred close together in semi-arid woodlands prior to white settlement. During uncommon periods of high rainfall there was widespread germination and establishment of shrubs, at the same time as abundant grass growth which predisposed the plant community to being burnt by man induced or lightning fires. Fire on these occasions killed most shrub seedlings and reduced the mature shrub component of the vegetation. Shrubs which survived fires recovered and over a period of years began producing seed again; some seedlings escaped being burnt and achieved adult maturity. In the years between fires it can be assumed a few shrub seedlings established in favoured areas (although most would succumb to competition from pasture plants). Subsequent fires arrested the progression to dominance by shrubs. Thus it appears that infrequent burning has in the past maintained a balance between pasture and shrubs.

Current management, involving grazing by domestic stock and fire exclusion, has reduced the competitive stress posed by pasture plants on shrub seedlings and removed the main lethal
agent. So now periodically there occurs a widespread establishment of shrub seedlings, where once wildfire swept them away. Thereafter the shrub component steadily becomes more dominant because shrubs live for a longer time than pasture plants and increasingly outcompete them for the limited supply of nutrients and water. To reverse this trend, grazing pressure needs to be controlled to husband the vigour of perennial pasture plants and thereby maximise competition for shrub seedlings. Then, at rare times of massive pasture and shrub proliferation, opportunistic prescribed burning should be incorporated into the management scheme. Removal of stock from some areas may also be necessary to conserve fuel for burning. Ideally burns should always take place after a dense establishment of shrub seedlings.

Notes: This is a set of notes provided for a Rangelands Society field day. They provide a summary of the results of research on Tundulya Station, near Cobar. It covers the background to shrub control, effect of fire in poplar box woodlands, seedling establishment, seasonality and fire intensity, effects of fire on mulga woodlands


Abstract: A theory for shrub control by prescribed burning in semi-and woodlands of eastern Australia is outlined. This theory is based on inevitable shrub increases which occur principally by episodic, widespread, mass establishment events. Wet periods which foster shrub establishment also promote abundant grass growth predisposing the plant community to being burnt. Fire then kills nearly all recently established shrubs and many of the adult shrubs, thereby controlling the shrub population. Today, fire is much less frequent and is prevented altogether in some areas. Prescribed burning before any potential wildfire season will both control shrubs and limit the spread of wildfires. Three constraints to the adoption of prescribed burning are recognised:

- economic benefits are mainly realised over a 10-20 year term
- graziers have little experience and infrequent opportunities to learn about fire;
- graziers are reluctant to accept the risks associated with burning.

If semi-arid woodlands are to be burnt at a frequency necessary for shrub control, grazing pressures may need to be reduced to husband the vigour of perennial pasture plants. Opportunistic burning should take place at times of widespread shrub seedling establishment. Prescribed burning is the only known method for broad-scale shrub control and relevant State departments and graziers are urged to collaborate in prescribed burning to a regional strategy, rather than property by property.

Notes: Fire is the only broadscale answer to shrub control. Historically episodic burning prevented shrubs from becoming dominant: Shrub increase occurs principally through episodic widespread mass establishment, wet periods fostering shrub establishment also promote abundant grass growth leading to likelihood of the community being burnt, fire kills all the newly established shrubs and adults.
1984/5 wildfires in the Cobar-Byrock pediplain - conditions were right for the first extensive fires across that region since 1921, not even the massive rains of 1974/6 produced sufficient fuel for wildfires in the shrubby environment but fires were controlled. There is evidence that periodic fires will control shrub populations - figure of range of mortalities of established shrubs after controlled and wildfire. Some species germinate in abundance after wildfire - never widespread and usually confined to areas of high fire intensity and surface seed density, survival depends on rainfall. After prescribed burns in 1979 pasture recovery was delayed until 1983 when rain brought a response 3 times greater on burnt land & this can continue for 10 years at least. TGP also plays a role in recovery. Provision of other areas with kangaroo feed is necessary to fully benefit from burns - requires regional planning. Experience required to carry out prescribed burns.


Abstract: Discusses: Fire Management Objectives (Control of woody plants; stimulation of new herbage growth; wildfire hazard reduction; fire exclusion; maintaining ecological diversity); Decision Making (fuel dynamics; frequency of burning; season of burning; intensity and completeness of burning; economics of prescribed burning); Post Burn Management; Methodology for Large Scale Burning (planning a prescribed burn; preparing firebreaks; lighting up; organisation of men and equipment; costs of prescribed burning); Conclusion

Notes: In tropical woodlands annual burning keeps most established woody plants in a stunted condition and inhibits their regeneration. In semi-arid & arid regions, where fires will only carry after sufficient fuel build up and woody plant populations will reach their maximum size and reproductive maturity between fires as a consequence plant species have different strategies for regeneration. Fuel, burn frequency and season all affect the dynamics of the burn.

Prescribed burning is a management tool for achieving the benefits of fire without risking damage to stock and property. It requires ecological understanding to know when to burn, experience in determining 'safe' weather conditions and decisiveness in utilising what are often fleeting opportunities. It is a relatively low cost management option.


Abstract: Three sites in a Eucalyptus populnea woodland in central New South Wales were sampled for the number and composition of seed in the surface cm of soil. There was a total of 3200 seeds/m2 beneath eucalypt canopy, 13800 seeds/m2 in grassy inter-tree areas and 4000
seeds/m² in bare inter-tree areas in April, 1975. These numbers were reduced by 23, 73 and 66% respectively during the subsequent 10 months, when there was no addition of seed. This decline was thought to be mainly due to predation, with germination as a secondary factor. Species composition of the seed pool differed between the three sites with seed of some species being only found beneath the eucalypt canopy or in the inter-tree areas. There were no seeds that were not present as plants in the community. Any attempts to restore this woodland to its former grassy nature should take into account the low seed population of many of the formerly common grass species and the high number of shrub seeds (>200/m²). Species distribution of seed was highly heterogeneous making adequate sampling very difficult. Extracting and identifying the seed took 8 to 12 man-h per 100 g sample.

**Notes:** The very high number of shrub seeds indicates the level of potential challenge by long lived shrubs in this district. In the exclosure between 1974 & 1977 225 *E. mitchellii*, 57 *E. sturtii*, 1635 *D. viscosa* and 393 *Cassia* [Senna] plants / ha established. In an adjacent paddock disturbed by a bulldozer 13500 shrubs/ha established including 7650 *Senna* and 1787 *E. mitchellii*.


**Abstract:** *Hakea preissii* has been identified as an undesirable increaser which has invaded formerly productive semi-arid pastoral lands of Western Australia. This paper reports a study designed primarily to assess the susceptibility of *H. preissii* to fire and to assess the effects of fire on the associated plant community. Plant survival was assessed by comparing the response to a low and high fuel load with untreated control plots. Fire intensities of 2900 and 9300 kw/m were achieved with fuel loads of 500 g/m² and were sufficient to kill 98% of *H. preissii* by two years after the burn. A fire intensity of 240 kw/m was achieved with 150 g/m² fuel load and was sufficient to kill 53% of *H. preissii* plants. Other perennial species, more highly regarded as sheep feed, including *Scaevola spinescens*, *Rhagodia eremaea*, *Enchylaena tomentosa* and *Maireana tomentosa*, were killed by fire while *Eremophila “crenulata”* and *Senna* species, which are regarded as undesirable increasers in this environment, were generally unaffected by even the most intense fire.

**Notes:** Low intensity fires killed >50% *Hakea preissii*, hotter fires killed about 100% - not a resprouter. *Eremophila* and *Senna* species more resistant to fire. Chenopods susceptible to fire. Needed fuel load of 150g/m² which is rarely available for fire to burn.


**Abstract:** Foreword to volume, no abstract
**Notes:** Definition of rangelands: Harrington et al 1984 'semi-natural ecosystems in which productive output is sought by simply adding domestic stock to a natural landscape'; Friedel 1994 'all those extensive lands, which, for reasons of climate or terrain, cannot support economically sustainable crop or timber production' - a transition towards multiple uses and values. Market based v's those that are not market based (Aboriginal, biodiversity etc)


**Notes:** Emission trading for rangelands: there may be opportunities and costs. Opportunities - storing of carbon in managed vegetation (estimates include 2.5-25 t C / ha and 20-30 t C / ha) and in rehabilitation of degraded soils (8 t C / ha) that can be purchased as emission offsets by countries and industries emitting CO₂ from fossil fuel use. This may offer a 30-50 year or more adaptation period until the carbon pool on a particular area of land is filled to capacity. Disadvantages arise from the greater methane emissions per unit product and per unit economic return for rangeland livestock when compared with livestock in more mesic regions as a result of greater emissions / unit feed uptake and lower rates of productivity and the potentially greater costs of fossil fuel-based inputs.


**Abstract:** Chronic, heavy livestock grazing and concomitant fire suppression have caused the gradual replacement of palatable grass species by less palatable trees and woody shrubs in a rangeland degradation process termed bush encroachment in South Africa. Grazing policy makers and cattle farmers alike have not appreciated the ecological role fire and native browsers play in preventing bush encroachment. Unpredictable droughts are common in South Africa but have deflected too much blame for bush encroachment away from grazing mismanagement. Bush encroachment is widespread on both black and white farms, although the contributing socioeconomic, cultural and political forces differ. Managers at Madikwe Game Reserve have reintroduced fire and native game animals into a formerly overgrazed system in an attempt to remediate bush encroachment, with encouraging preliminary results. A bush control program is needed that educates cattle farmers about the ecological causes of bush encroachment and encourages the use of fire and native browsers as tools for sustainable grazing management.

**Notes:** Rangeland degradation has been observed on every continent with arid and semi-arid savannas and global desertification is primarily caused by grazing by livestock. The proportion of desertified arid rangeland has not been well quantified but is believed to be 49-90% in Africa. Many scientists have discussed the potential link between desertification and global
climate change but no clear link has been established. Encroachment by unpalatable trees and shrubs is the best known cause of desertification. Climate change and increased CO\textsubscript{2} concentration have been suggested as causes for bush encroachment but livestock grazing is more strongly implicated (Archer et al 1995). Estimates that the grazing capacity or ecological carrying capacity of savannas in South Africa has been reduced 50%.

**Savannas:** defined as having a continuous grass understorey interspersed by a discontinuous woody overstorey. Productivity primarily determined by rainfall. In RSA there is an annual drought as well as irregular interannual droughts. Savannas are inherently unstable with the ratio of woody plants/grasses determined by climate, soils and fire and herbivore disturbance regimes. The combination of heavy grazing and fire suppression over many decades appears to push the system beyond a threshold into a relatively stable state that is not readily reversed naturally - an inherently unstable savanna can gradually transform into a relatively stable thorn woodland.

**Grazing:** Fencelines erected to restrict livestock movements have shortened or eliminated vegetation recovery periods and constraining livestock movements forces livestock to graze the same pasture continuously which reduces ecosystem resilience or the ecosystem's ability to respond to varying climatic conditions. Boreholes and wells further facilitate continuous grazing of vegetation which is adapted to rest during the dry season. Natural veld fires have also been actively suppressed or passively precluded by livestock that removed the fuel - all this has led to bush encroachment.

**Drought:** The detrimental effects of low rainfall are more likely felt among inhabitants of overexploited lands. High interannual variability makes it very difficult to detect long term change.

**Fire** generally rejected by white farmers in SA as 'not natural'. Academic knowledge regarding fire effects on rangeland vegetation has generally progressed from general hostility in the 1920s to widespread acceptance in the 1950s but this has failed to reach the cattle farmers.

**Native stock:** Included grazers and browsers and species with different dietary preferences than an equal mass of cattle all with the same preference.

Recommendations: rotate grazing so only a quarter of the area used at a time, established unwatered ‘reserves’ that will be buffers to regional over-utilisation of the natural resource base and introduce game species that will roam freely and can be communally cropped and marketed.


**Abstract:** There are broad similarities in the issues and challenges facing the rangelands in Utah and Australia, despite there being numerous contrasts as far as climate, vegetation, water availability, wildlife and other factors are concerned.

**Notes:** Utah's rangelands: more varied and productive than in Aust although includes arid areas, more variable topography and harsher winters at higher altitudes. Mostly cattle ranching under a permit system on public lands but multiple use is also a universal feature -
includes forestry, mining, conservation, wildlife habitat, water resources and recreation. Fire management: conflict between the need to use fire as a vegetation management tool and the risks to people, property and some land uses. Generally accepted that there has been a lack of fire since European settlement with the impact of grazing that has created the woody weed problem where Juniper trees now dominate parts of the landscape - reducing water resource and grazing values. Aspen ecosystems also affected by lack of fires but because water resources, pasture production, wildlife habitat, biodiversity and timber production are in decline because they depend on fire for regeneration and to reduce competition from fire-sensitive conifers. Prescribed fire now seen by managers as an important management tool but not favoured by ranchers due to risks to assets. Because of fuel build up wildfires are ferocious when they do occur as demonstrated by fires in 2000 at Yellowstone National Park. As a result of lack of management burning, many areas are becoming less capable of supporting a diversity of uses and natural resource values.


Notes: It seems that at least 3 fires in succession may be necessary to control shrubs before they become dense but the chances of sufficient fuel building up in several years in a row is remote in the Wanaaring district because of low rainfall, and the use of artificially spread fuels such as hay is impractical. Once scrub becomes thick fires will just not travel through it and it is hard to beat a bit of thick scrub as an effective firebreak as the severe fires of 1979 showed.


Abstract: Holistic management schemes based on high mortality of unwanted woody shrubs can be initiated through the use of selective herbicides. Subsequent maintenance of treated rangelands by use of fire, mechanical methods and individual plant treatment, combined with proper grazing management, will extend treatment effectiveness and improve economic returns.

Notes: Woody shrubs described collectively in this paper as brush are mostly members of the Leguminosae - including Mesquite (35 million ha in SW USA, Mexico etc, vinal (Prosopis) in Argentine and Paraguay, Acacia species occupy >20 million ha in southern Africa and Acacia in Australia. 

Methods of control: burning - frequencies & intensities of pristine fires are not well documented nor is the extent to which they burned but can assume that areas protected from
burning and overgrazing accumulated greater fuel loads and when burnt achieved higher heat intensities and greater mortality of woody species. Conversely excessive grazing reduced fuel loads and with fire suppression policies stopped natural fires, allowing woody weeds to spread - established brush may be difficult to remove using only fire, especially cool season burning - in east Africa burning did not eliminate brush but merely kept it at low levels; biological - no evidence of success; mechanical - tends to need the help of other methods for successful removal of woody weeds and is expensive; and chemical.


**Abstract:** The ridges of the Cobar pediplain generally have only a sparse herbage cover. Much of the incident rainfall is reputed to run off, perpetuating the low pasture productivity and causing erosion. Woody shrubs have often invaded the woodlands of the pediplain. On some gentler sloping (1%) ridges dense patches of shrubs surround large eucalypts and together are known as 'thickets'. Between these thickets relatively sparsely shrubbed areas ('interthickets') occur. Runoff from small plots situated in thicket and interthicket areas of shrub invaded poplar box woodland was recorded during 1975-1981. Half the plots had been partially cleared by pushing over all shrubs with a bulldozer ('shrub-pushed', in contrast to 'unpushed'). Soil losses from the plots were measured over a four year period. Rainfall during the study was 26% greater than the long term average for the area, and provided many runoff events, particularly from intense summer storms. Runoff averaged 26% of rainfall for unpushed interthicket areas while thicket runoff was negligible. Runoff from the shrub-pushed plots was c. 25% less than from their unpushed counterparts, but this difference was not significant at P < 0.05. During the December-March period monthly runoff from unpushed interthicket plots averaged 41% of monthly rainfall in excess of 12 mm, while for the other eight months runoff averaged 24% of monthly rainfall in excess of 9 mm. Soil losses were greater during the stormier part of the year, with long term soil loss rates equivalent to 25 mm per 1000 years from enclosed interthicket plots and 55 mm per 1000 years from the grazed interthicket plots. Shrub-pushing appeared to increase soil losses in the short term but after two years soil loss rates decreased to be less than those from unpushed plots. Estimates of likely interthicket runoff based on long term rainfall records had a median value of 77 mm per year, or only 64% of that observed during the study period. Over the 88 years the 5 year moving average of estimated runoff fell to as low as 40 mm per year. The results are discussed in the context of waterspreading.


**Abstract:** Soil water was monitored over a six year period in an intact shrub invaded semi-arid Eucalyptus populnea woodland (control) and on areas which had been treated by either
shrub-clearing, or by ringbarking of trees and shrub-clearing. Measurements were made under both the shrubby thicket areas near the eucalypt, and the sparsely shrubbed interthicket areas more distant from the trees. Average soil water storage over the six years for all treatments was only 26 mm. Much of this water was stored in the upper 500 mm of the profile and hence was susceptible to direct evaporation from the usually bare soil surface. In the intact woodland and following wet weather, significantly more soil water was stored under thickets than under the interthicket areas. With the return of dry weather this extra soil water was rapidly depleted, and thicket soils would often become drier than interthicket soils. After prolonged dry weather, soil matrix potentials of -10 to -12 MPa were recorded at a depth of 500 mm. Matrix potentials by this time were least negative under thickets. Shrub clearing without ringbarking increased thicket and interthicket soil water storage by 17% and 23% respectively. The ring-barking and shrub clearing treatment increased thicket profile storage more than that of the interthicket (81% and 64% respectively). The effect of ringbarking was often pronounced at a distance of 25 m from the tree. The contrasting soil water response to the two treatments indicated that in this semi-arid environment only a relatively small change in soil water balance may accrue from incomplete clearing. The removal of both shrubs and trees is probably necessary to make a large difference to soil water storage.


Abstract: ‘Fundamentally, the grazier’s objective in the arid zone is the highest possible net income without damage to the capital asset. In addition we expect ... to pass on our properties to our sons in a better condition than we found them.’

Because of the constant threat of rangeland degradation there is a real need for land managers to be aware of the interactions between landscape, soil, vegetation, climate and grazing animals which affect the productivity of the soil-plant system. These interactions affect the potential productivity through a series of processes such as the break down of soil structure, the redistribution of water at the soil surface and the removal or deposition of soil and plant nutrients by wind and moving water.

Notes: Discusses: Meteorological forces on the soil-plant system, soil water storage (size of the soil water store, fate of rainfall, rainfall interception and stemflow, infiltration and surface redistribution, evaporation and transpiration, soil water regimes), productivity of runon water, Soil degradation (degradational processes, grazing and soil degradation ), processes and management of rangelands.

Soil degradation: structural breakdown, erosion by wind and water, nutrient losses, salination - occur naturally but accelerated by pastoralism. 15% of Aust rangelands are highly erodible & 59% moderately erodible - adequate plant cover is essential to protect susceptible soils from wind erosion. Grazing by livestock may either affect the soil directly by hoof action or indirectly by reducing plant size, plant number, and the litter layer. The direct role of soil
surface pulverisation by stock can be important in those soils which form relatively erosion resistant crusts. The loss of plant cover is the most significant effect of grazing stock on soil stability. Total Grazing Pressure on rangelands should be managed to ensure that they maintain adequate cover of perennial plants so that the degradative processes are in dynamic equilibrium with the natural renewing agencies of nutrient cycling and seedling recruitment.


**Abstract:**

Contents:
1. A brief history of Australia's mammals
2. The Pleistocene megafauna
3. What caused the magafauna extinctions?
4. Two dating problems: human arrival and megafauna extinctions
5. The changing environment of the Pleistocene
6. Testing hypotheses on megafauna extinction
7. The ecological aftermath
8. Environmental change and Aboriginal history
9. Dingoes, people and other mammals
10. Mammal extinction in European Australia
11. What caused the recent extinctions
12. Interactions: rabbits, sheep and dingoes
13. Conclusions

**Notes:** These notes only include references made to the impact of fire on fauna. *Fire and the remaking of Australia:* There is a problem with the general hypothesis that Aboriginal people made major changes to Australian vegetation which then drove the megafauna extinct - but many of these species preferred the open woodlands favoured by burning. Another version might be - before the arrival of many people many of the habitats of inland Australia had a complex layer of shrubs and small trees which was important to the large number of browsing megafauna. Also postulated that Aboriginal burning might have caused a rearrangement of habitat mosaics, creating a fine-scale patchiness of scrub and tree communities that disadvantaged large browsers but favoured grazers and small mammals. *People fire and vegetation:* No doubt that fire was a significant environmental factor before the arrival of humans. General review of ecological, anthropological, paleoecological data suggests that there was NOT an unprecedented and continent wide increase in burning with associated vegetation change when people first came to Australia. Analysis of pollen at Cuddie Springs identified a charcoal peak at about 28kyears that was not associated with a major vegetation change but there is an earlier peak which coincided with a decline in Casuarina and increase in chenopod shrubs - before the arrival of people. Much of the variation in charcoal concentrations can be explained by climatic variation not human impact. Burning appears to have been much more widespread through most of the last 10 kyr (the
present interglacial) than in the previous interglacial 130 kyr ago. There seems to be no doubt that fire increased over the last 120 kyr but the arrival of people in the middle of the last interglacial cycle had very little impact on this trend although human influence in the last few thousand years probably strengthened.

*p 124 Fire:* Published pre-histories show a variety of patterns of change in fire through time with increases in charcoal before the megafauna extinctions just as common as increases after. It is possible that the kind of shrublands that expanded after the megafauna went extinct were not fire-promoting e.g. chenopod shrublands.

*Fire is for Kangaroos:* Although there is very little evidence of an increase in burning as a direct and immediate consequence of human arrival in the middle of the last glacial cycle, by the time of European arrival firing of the landscape was almost entirely in the hands of Aboriginal people but when and how? Rather than imposing a fundamentally different fire regime on Australian environments the effect of people was to accentuate a pre-existing climate driven trend towards fire and more flammable and fire-adapted vegetation. It could be argued that Aboriginal people made no difference at all to the re-creation of Australia as the most flammable continent. Evidence from Arnhem land that people shape the vegetation in very many ways. There seems no doubt that Aboriginal use of fire changed the ecological patterning of plant communities within intensively managed areas like central arnhemland and possibly altered the larger-scale distribution of vegetation types. One of the most common goals was to increase the harvest of large mammals by using fire to maintain grassy habitats and in the process of hunting - described by Arnhem land elder.

Aboriginal burning generally thought to have created a fine mosaic favourable to CWR mammals that have become threaten or extinct. However, overall the evidence suggests that changed fire regimes have made little if any direct contribution to recent mammal extinctions although the idea remains attractive for deserts because it explains why some mammals declined there as the Aborigines left but suggests it is not the explanation for the disappearance of the CWR mammals - changed predation is the key hypothesis.

*The sheep plague:* 1860-1894 sheep numbers rose from 1 million to 13 million then collapsed to less then 4 million by 1902. Generally averaged around 6 million since. Add to this the effects of rabbits and drought and it is hard to imagine that the ecosystems of NSW had ever been struck a more savage blow.

**Johnson P. W. & Evenson C. J. (1992) Ploughing, grasses and fire to control green turkey bush (Eremophila gilesii) in south western Queensland. In: Fifth Queensland fire Research Workshop, Charleville, Queensland.**

*Notes:* Overgrazing, lack of fire and winter rainfall have contributed to the woody weed increases and therefore decline in productivity. Slashing, ploughing, heavy grazing and controlled fire have proven successful for the control of green turkey bush on a small scale. While fire is the most economical method over large areas, sufficient grass fuel (>1000 kg/ha) is present only about once every 8 years according to work in the 1970s & 80s. An economic combination of treatments is necessary to increase available fuel to use fire & once recovered judicious management is required to avoid future problems. Ploughed strips sown to grasses
and fire to control dense stands of turkey bush near Charleville has been shown to be effective.


**Notes:** Study objectives: To work with graziers to develop management strategies for woody weed problems in western Qld; To promote adoption of these strategies by land users and administrators; To undertake research pertinent to missing information; Increase the relevance and value of information by pursuing research, monitoring and extension leads from the project.

Research: mechanical treatment and/or burning followed by foliar herbicide application considered to be showing promise for woody weed control. Mixed results from foliar herbicides. Residual herbicides still showing effectiveness after nearly 7 years. Mortality rates from chaining, regrowth rates on gidgee also reported. Blitz grazing with goats had uneven impact on gidgee mortality rates.

Mild fires controlled turkey bush by reducing canopy cover and plant density but not sandalwood and did not harm pasture even after chaining as well.

'The most important result of this study is the demonstration that burning must be implemented for woody weed control particularly turkey bush despite the short term returns. Benefits will not be maintained without follow up burns. The pasture responded well following the first substantial grass growing rain. Burning during extended dry seasons does not damage pasture.


**Abstract:** Fire regimes have been a major driving force in the maintenance of biodiversity in many Australian ecosystems. Currently fire regimes are manipulated across much of the continent and affect, in often complex ways, the biodiversity of both relatively natural systems
and those that are converted, fragmented, invaded, or otherwise modified. This chapter focuses on the use of fire for managing biodiversity, drawing on the considerable advances in knowledge that have occurred in fire ecology and management in the last 2 decades. The policy and legislative environment within which fire managers operate is briefly addressed, but the main discussion considers a number of principles and approaches for the use of fire as a management tool including the use of local populations and functional groups and variability within critical fire regime thresholds. These are applied in an adaptive approach to management that recognises the importance of setting explicit goals, precautionary management practices, experimentation, risk assessment and the need to implement monitoring so that management practices can be evaluated and potentially modified. Part of this approach will be to try to include the unpredictable (especially unplanned fires) in management planning. An ecosystem-based, landscape-scale approach to planning and management is advocated. To help achieve biodiversity conservation goals, spatial and temporal variability in fire regimes should be promoted, fire management targets should be defined as ranges rather than optima, and focus should especially be directed at groups of species with ecological traits which render them most susceptible to decline under different fire regimes.

Notes: Pre-European fire regimes are essentially unknown for the majority of the Australian landscape but rather than trying to recreate the unknown the solution is to move forward to new management approaches based on sound and innovative fire science.

Legislative and policy framework for biodiversity conservation: Historically much of the legislation about fire management in Australia has been about fire prevention and suppression, minimisation of loss of life and property. Legislators respond to deaths by attempting to impose control on fire but often this narrows the range of acceptable or achievable fire regimes and in some cases outlaws regimes required for species conservation. It is necessary that existing conservation conventions and agreements are translated into specific legislation that recognises that fire regimes play a fundamental but complex ecological role rather than being a simple destructive agent. Legislation of relevance to biodiversity conservation (stemming from the Convention on Biological Diversity, Rio Summit) - EPBC Act 1999, and State legislation relating to fire planning and management for biodiversity e.g. at Tarawi nature Reserve the fire management plan operates under the NSW Rural Fires Act 1997 which defines statutory obligations of land managers and provides for the establishment of bushfire management committees to integrate fire management across the State. The plan also operates under the NSW NPWS Act 1974 which defines the role of nature reserves and requires that the fire management is not in conflict with the plan of management ot the Threatened Species Conservation Act 1995. Off reserve management of indigenous ecosystems is also increasingly recognised as a critical component of landscape management - so the management of indigenous biota on leasehold freehold and Aboriginal-owned lands is also important for conservation.

Fire regimes and biodiversity: Fires have long been instrumental in promoting diversity in this system, being a significant source of textural variation within the broad environments and in mediating the occurrence of the relatively small patches of contrasted environments within a broader matrix.

Examples of species declines associated with fires: Fire regimes have been implicated in local
extinctions of several vascular plant species across Australia. At the population level, fire driven plant extinctions are likely to be widespread. Fire regimes have also been implicated in the decline of many bird species. Inappropriate fire regimes were implicated in the decline of 51 threatened bird taxa, most of which required long-unburnt vegetation and longer fire intervals.

Managing for biodiversity conservation key approaches and principles: Reducing complexity: local populations, functional groups and management thresholds - The full spectrum of biodiversity cannot be maintained if fire management only addresses single species in isolation. Their roles within ecosystems will also vary from place to place depending on associated biota. Flexibility: defining fire management targets as ranges rather than optima - this offers greater flexibility to deal with uncertainty and to resolve potential management conflicts. Resolving conflicts between multiple management goals: temporal and spatial options - Conflicts often arise between fire management goals. Species or species groups may have requirements for quite different regimes - temporal variability in regime between species; fire landscape mosaics / spatial variability in fire regime eg Mala in spinifex habitat in Tanami. Accommodating uncertainty and new knowledge: risk assessment, adaptive management and monitoring - consider alternative strategies to meet an explicit management goal, favour actions that are informative, reversible and robust to uncertainty, experiment on alternative options, validate assumptions underlying management decisions, monitor results of management, modify decisions in the light of new information. Fire as a restoration tool - Sometimes the use of fire can exacerbate a weed problem and follow up work is essential - this is not well developed. Aboriginal Fire Regimes - Aboriginal fire regimes were instituted largely to maintain access to food resources, whereas conservation management may involve very different goals such as protection of a rare plant species which may have been devastated by Aboriginal burning. There can be conflicts as in Kakadu.


Abstract: The Australian arid zone is a large complex area. In order to maintain its biodiversity, it essential that landscape-wide and long-term analyses form the backdrop to the development of management strategies. From the current knowledge of the biodiversity and ecology of the arid zone, it is evident that there has been a loss of about 50% of the mammalian fauna and a reduction in the distribution and abundance of bird and reptile species since European settlement. But our knowledge of arid ecology is limited, with the majority of data representing a single snapshot in time, from sites that are a mere pinprick on this landscape, which constitutes 70% of the area of Australia. Scale, both spatial and temporal, is a critical issue underlying our understanding of this landscape. In this paper, three key elements affecting the biodiversity and ecology of this landscape are discussed: climate, fire and European settlement.
Rainfall is known to be highly variable in space, time and intensity yet it is routinely described by mean values. Understanding long term trends is of greater value for sustainable management. CUSUM analysis is a valuable technique for demonstrating rainfall trends and illustrating when trends change from a sequence of drying years to an increasing trend. It also provides an indication of water availability in the landscape. Most of our ecological knowledge has been collected within the last 50 years, a period of increasing water in the landscape when conditions have been good more often than they have been bad. Superimposed on this is the episodic nature of major ecological changes, with naturally occurring floods and fires shaping the landform and distribution of vegetation communities, in addition to the more subtle successional changes. Spatial heterogeneity is another critical element, with fertile patches ranging from centimetres to hundreds of kilometres in size scattered across an infertile landscape.

There is no one recipe for the sustainable management of the arid landscape. Flexible, adaptable management strategies, based on a long-term understanding and analysis, are required. It will also be critical to effectively engage land managers through the development of environmental stewardship programmes and rewards to encourage management for biodiversity alongside production. Integral to these management strategies is the careful use of fire, a tool lost by the removal of Aboriginal management. Some ecological parameters have been defined for the centre and west of the arid zone, where most research has been carried out. While some of these are relevant in the east, it differs ecologically and in terms of the severity of the impact of European settlement. There is an urgent need for further ecological research in the east of the arid zone.

Notes: Summarises changes to the fauna of the arid zone and highlights the lack of information for NSW - analyses that do exist paint a picture of decline. Climatic issues are highlighted with an analysis of rainfall distribution using CUSUM analysis v’s annual means suggesting that this is a better approach for understanding the dynamic of the arid zone. In broad terms rainfall at Broken Hill was in a constant decline overall between about 1920 and 1950, had a small increase in 1950s followed by decline until the 1970s after which there was an overall increase until about 2000. These trends are similar throughout western NSW but differ from central Australia. Discusses the overall impact of fire regimes and wildfire events in central Australia on biodiversity. Suggests that as vast wildfires had been a feature of the ecology of arid Australia it is unlikely that Aboriginal patch burning would have completely eliminated them. Aboriginal people rarely burnt mulga. Fire is not a feature of the current ecological dynamic in the rangelands of western NSW but it remains important in Mallee communities. Impact of European settlement: Highlights comments from the 1901 royal commission into the western lands including about the changed soil qualities, weed problems etc.

Abstract: Over the last 20 years, the counting of charcoal is association with pollen in the construction of paleoenvironmental records from swamp, lake and marine sediments has become routine. This has provided a substantial, although methodologically variable and geographically biased, data set with which to examine the history of burning on the Australian continent. Two generalised records from southeastern Australia demonstrate a general increase in burning within the latter part of the Tertiary period in line with reduced precipitation, increased climatic variability and development or expansion of sclerophyll forest and heath vegetation. The one continuous record of vegetation and burning from the early part of the Quaternary suggests that this period may have experienced relatively stable environmental conditions. Increased fire activity is evident in the majority of records extending through at least the last glacial/interglacial cycle, particularly during drier glacial periods and during times of major climate change. A focus on southeastern Australia for the last 11,000 years, a place and period containing the bulk of charcoal records indicate high fire activity over the last few thousand years, with a major peak coinciding with the early phase of European settlement followed by reduction within recent decades to early Holocene levels. It is demonstrated that climate has exerted the major control over both fire activity and vegetation change. There is a notable increase in fire activity centred on 40,000 years BP which, in the absence of major climate change around this time, is considered to most likely indicate early Aboriginal burning. The impact on the vegetation was largely to accelerate existing trends rather than cause a whole landscape change. It is difficult to separate the effects of climate and human-induced burning subsequent to this time until the arrival of Europeans.

Notes: Reviews all the pollen/charcoal studies completed at the time. The palynological records with charcoal curves over the last 100,000 years BP are considered - variability between these records has led to many theories being postulated about the relationship between fire, climate, various components of the vegetation and people. Analyses records from SE Aust to assess these conclusions - overall impression is that fire activity has been relatively constant over the Holocene with greatest variation during the period of European occupation. Data suggest that burning increased during the early part of European settlement to levels higher than at any other part of the Holocene in all major veg types. This period was followed by a reduction in burning to present levels which are, on average, lower than at any other time during the Holocene but levels in dry forest and heath appear to be higher than those in the early-mid Holocene. Timings of high onset of fire activity are difficult to determine accurately. Suggestions of an increase in a shrubby understory due to disruption of the Aboriginal fire regime cf grasses in an open forest is not supported by study from East Gippsland in which an increase in grasses was detected during the early European high burning phase and a following decrease with fire control strategies. The relative importance of climate and human influence in the increases of evidence of fire increases is difficult to assess but evidence from NZ where there were no people during these periods indicate that ENSO had a significant influence and that climate was the major driving force. There is little support for the postulation that Aboriginal burning created a change from Casuarina woodlands to
Eucalypt/heath woodlands. Although Casuarina woodlands declined they did so at different times and without an obvious burning cause. The development of eucalypt/heath woodlands would have favoured fire activity which may explain the increase in fire activity through the Holocene. Evidence for some human impact at about 40000 years BP is strengthened - there was no major global climate change - the evidence indicates a response of vegetation to burning rather than vegetation change due to higher fire activity. The change appears to represent an acceleration of an existing process rather than a singular event & the degree of change proposed is much less than for the climatically sensitive humid tropics region. Fire activity has been higher in the later Holocene and although it corresponds to an intensification of human occupation it is more parsimoniously explained by vegetation changes associated with drier and more variable climatic conditions.


Abstract: Introduction: The living legends and mythology of the Central and Western Desert regions contain many references to fire. Fire obviously means many things: punishment, hunting, signalling, ceremony, the hearth, clearing of country and improvement of country are all stated or implied. The Aborigines of the Central and Western Deserts are as one with the eternal ones of the dream in their present and recent past fire-practices. I examine early European records to indicate the nature and extent of fires, and to suggest that large Aboriginal fires were not accidental, random or otherwise uncontrolled. Following this, records from 1970-81 will show that Western Desert Aborigines still perceive fire as an important tool which can be used to improve their country.

Notes: European records: fire and smoke reported but problems with interpretation because extent and purpose rarely given or speculative and some of these must have been caused by lightning. There are also great differences between the explorers journals depending on their interests and editing. However, it was apparent that widespread burning did occur and was controlled but based on fuel recovery, fires would have occurred with at least a 3 year interval. Areas not burnt for 3-10 years were almost certainly of very considerable importance to Aborigines as refuge for animals etc. Focal points for burning - in vicinity of hills, along river and creeks, near claypans and soakages. Spinifex was the most commonly burnt plant. Mulga is very susceptible to fire and prior to 1917 fires in mulga country were rare. 2 records from Gosse of burning mulga were in 1873 at which time there appears to have been a lot of rain (flowing streams etc) which would also have created a fuel build up. A large scale increase in burning appears to have occurred immediately prior to rains. Evidence exists for small patch burning (March to August) & more extensive burning, Oct-Jan occasionally resulting in very large fires. The regular firing of the landscape produced complex mosaics of burnt and regenerating country, pyrrhic successional stages were exaggerated and the productivity of the landscape was increased as the number and variety of animals increased as did the fire weeds which were important food sources. Suggests that 89% of the spinifex was burnt over a 10 year period. Of the unburnt 10%? Aborigines knew the susceptibility of mulga to
destruction by fire and preferred not to fire it and the presence of dense & very dense mulga meant that there was no spinifex or other grass fuel present to carry a fire.


**Abstract:** In situ aircraft measurements of trace gases and aerosols were made in the boundary layer (BL) and free troposphere (FT) over Indonesia and Australia during the Biomass Burning and Lightning Experiment (BIBLE)-A and B conducted in August–October 1998 and 1999. Concentrations of ozone (O₃) and its precursors [CO, reactive nitrogen (NOₓ), non-methane hydrocarbons (NMHCs)] were measured in these campaigns to identify the sources of NOₓ and to estimate the effects of biomass burning and lightning on photochemical production of O₃. Over Indonesia, in-situ production of NOₓ by lightning was found to be a major source of reactive nitrogen in the upper troposphere during BIBLE-A. In some circumstances, increases in reactive nitrogen were often associated with enhancements in CO and NMHCs, suggesting that the sources were biomass burning and fossil fuel combustion, followed by upward transport by cumulus convection. Over Australia the levels of O₃, CO, reactive nitrogen, and NMHCs were elevated throughout the troposphere compared to those observed in the tropical Pacific. However, the mechanisms responsible for the enhanced concentrations in the BL and FT are distinctly different. The emissions from biomass burning that occurred in northern Australia were restricted to the BL because of strong subsidence in the period. In the FT over Australia, elevated concentrations of O₃ and its precursors result from injections of emissions as the air masses travel over Africa, South America, the Indian Ocean, and Indonesia en route to Australia. In all cases, O₃ levels in the biomass burning plumes were enhanced due to photochemical production.


**Abstract:** As well as being important components of biodiversity in their own right, plants reflect the physical environment, are the primary target of many of the pressures acting on rangelands, and are relatively amenable to measurement. Hence, measurements based on plants have considerable potential to be efficient indicators of the response of rangeland biodiversity to land use. A recent report commissioned by the National Land and Water Resources Audit recommended a core set of 11 indicators, six of which relied on measurements of plants. These were trends in (i) the extent of clearing; (ii) the cover of native perennial ground-layer vegetation; (iii) the distribution and abundance of exotic plant species;
(iv) the distribution and abundance of fire-sensitive species; (v) the distribution and abundance of grazing-sensitive species; and (vi) the distribution and abundance of listed threatened entities. Most indicated responses of plants to pressures acting on them. Only two (clearing and exotic plants) related to pressures. We recommend that the set be expanded to include two additional pressure indicators, one for grazing and another for fire, in recognition of their extent and potential influence on rangeland biodiversity. We also recommend that benchmark sites be included in all ground-based monitoring programmes to provide reference standards for those biotic indicators about which little is known. Assessments of the current state of knowledge about these indicators for two case-study regions, the Gascoyne–Murchison strategy area and Cape York Peninsula, have shown that it would be possible to monitor most of them directly at regional scales, but that current monitoring programmes fall short of achieving this.

Notes: Cites most potentially damaging pressures on plants as grazing, clearing, weed invasions, inappropriate fire regimes and global change. Short-lived plants may prove to be the most sensitive indicators of degradation.

Pressure indicators: Domestic livestock - factors relating to landscape heterogeneity, as well as management tools such as watering points, fences etc need to be taken into account when modelling grazing pressure; non-domestic grazers - feral grazing is a key threatening process. Fire regimes: use of satellite data for monitoring fire regimes.


Abstract: Contents:
Part I - Ch 1 The Central Australian Desert; Ch 2 Desert People; Ch 3 Fire; Ch 4 Plant Uses
Part II - Preface to plant list; Plant list pp 75-301
Appendices.

Notes: In the central Australian deserts, after several good seasons build up of flammable material can mean that a single wildfire lit by lightning in summer can burn out large areas, having a devastating effect of flora and fauna if not followed by rain. Hard to believe Aboriginal people could have survived if this had happened in the past. They used it as a survival 'tool'. Outlines their various uses of fire. In particular fire increased the yields of plant foods although they probably rarely burnt the country with this express purpose. Many important food are encouraged by fire but others are not and the Aboriginal burning system results in optimum food production from both these groups by producing a mosaic of vegetation in different stages of fire recovery. Aboriginal people no longer systematically carry out this burning system because they were actively discouraged by European settlers if they did because it reduced the amount of grass for the cattle and changes to the vegetation by introduced grazers (cattle and rabbits) made it impossible to maintain the system.

Effects of changes in burning practices: In the early 1920s a sequence of 3 very good seasons resulted in high build up of flammable plant material. This led to a devastating bushfire
reputedly from Oodnadatta to Tennant Creek (1000km). With little follow up rain (6 year drought) and rabbits the long term effect was devastating. Research into the Mala (*Lagorchestes hirsutus*) shows that it appears to depend on Aboriginal mosaic burning and its demise has been directly influenced by the loss of this. Mosaic burning in the top end also so that at the end of the dry season when lightning strikes are more common, hot widespread fires are prevented.


**Abstract:**

Contents:

Ch 1 A Flaming Desert; Ch 2 Spinifex; Ch 3 Fire Sensitive Plants; Ch 4 Fire and the Red Devil; Ch 5 The Changing Desert Landscape; Ch 6 Fire and River Systems; Ch 7 Fire in some Other Parts of Australia; Ch 8 Animals and Fire; Ch 9 Aborigines and Fire; Ch 10 When, How, Where; Ch 11 Fire and Future

**Notes:** Contains some very valuable observations about plants and plant communities in central Australia accompanied by speculation regarding the influence of aboriginal burning and fire in general in shaping the distribution of plant communities across the landscape and the takeover by spinifex species.

**Spinifex:** Why is the most common plant in much of the Australian deserts is not a shrub but a prickly grass? While it is a grass it is a very shrub-like grass - long lived perennial with a deep root system, rather than drop leaves to survive drought it can roll them up and shut down. It is also a take-over plant. Shrubs will take over if spinifex is not burnt regularly or with cool fires.

**Termites:** The most important grazing animals in the desert are termites.

**Fire-sensitive plants:** Mulga is the most common fire-sensitive plant in the centre. It dies when burnt but will recover quite well if followed by rains from seed. In long-unburnt mulga communities it is not dominant but shared with a variety of other woody species. These can be divided into dry-jungle and secondary succession species.

**Soil-crusting plants:** The 'skin of the earth'. Has demonstrated in the previously overgrazed Simpsons Gap National Park that these plants returned after the exclusion of cattle. After a big rain in 1983 (13 years after cattle removed) soil crusting plants covered much of the former degraded areas. When cattle were still there gutter near the visitors centre was losing more and more soil after every rain. 13 years later the erosion had almost completely ceased because a coat of vegetation protected its walls - the main protecting agents being the soil-crusting organisms. A similar area still being grazed was continuing to be eroded unabated. Resurrection plants play a similar role in sandy areas. These are very fire sensitive.

**Fire:** Shrubs are favoured by winter fires due to increased germination, survival and growth after burning - spinifex dominance is decreased; winter fires are more patchy; winter fires are more patchy, more animals survive, there is less wind and water erosion, less nutrient loss, can be used to reduce spread of summer wildfires. **Fire frequency** - using time as a measure is a real problem given the uncertain rainfall - much better to refer to the amount of preceding rainfall but both type and timing of rainfall are important. In general most spinifex
communities are ready to burn after about 7 or 8 years, depending on the species. Dense mulga communities usually only carry sparse grasses so it is only after exceptional seasons that there is enough fuel to carry fire – maybe every 25 years – allowing time for the relatively quick growing mulga to mature from seedlings and produce abundant seed. Soil and fire - massive soil erosion can occur after vegetation removed by the fire and loss of nutrients.

Fire and Rivers: Fire induced erosion appears to have not only blocked up river systems but also to have reduced the water flowing through them.

Fire management on central Australian National Parks: Fink Gorge NP - fire management system implemented protects the remaining fire-sensitive vegetation and ensures future expansion. All veg has been mapped, different spinifex communities delineated, fuel measured. Ranger Dennis Matthews found that burning the spinifex ASAP after rain causes the least possible damage - soil crusting organisms are little affected as are almost all other plants and animals except the spinifex.


Notes: Postulate that in central Australia a tight mosaic of regular burning was the practiced land management strategy of the Aborigines.


Abstract: The effects and significance of fire on major vegetation resources of the region is presented. It is shown that many of our important and long-lived trees and forage shrubs are not only susceptible to fire but have regeneration which is very palatable top stock and feral grazing animals. Broadscale losses of those plants is now occurring.

Notes: Most of the important and widespread trees and shrubs occurring in the arid zone are quite susceptible to fire but able to regenerate fairly well after a subsequent rain. However those trees of greatest value to the pastoral industry are being effectively eliminated by stock and uncontrolled grazing by rabbits. The implications for the region are profound and in many areas we are now witnessing the dramatic transformation of woodlands to degraded annual pastures and inedible shrubs.

Abstract: Introduction: There is sufficient evidence available to suggest that Aboriginal fires were responsible for converting large areas of forest into grassland plains and savanna woodlands which were subsequently maintained as disclimax communities by regular firing.

It was the sight of these extensive grassy plains and open woodlands, particularly in the interior of the mainland which made the rangelands so attractive to the early pastoralists and their voracious livestock.

Notes: Semi-arid and arid zones: In these rangelands, wildfires generally occur in the first dry season following one or several years of above average rainfall when there is an abundance of dry-herbage fuel. Undoubtedly it is the short-lived grasses in most cases that make the greatest contribution to these ephemeral fuel stocks but the dry Asteraceae are also highly flammable. This contrasts with the sclerophyll forests where high fire-risk periods follow droughts which cause the accumulated litter to desiccate and become highly combustible. The distribution of grassy fuels across the rangelands demonstrates the dominant influence of Stipa, especially variable spear grass as a fuel in the winter rainfall zone and hummock grasses through much of the summer rainfall rangelands to the north. The Stipa dominance in the south has been attributed to the elimination of Themeda australis, a warm season perennial which was originally abundant particularly in the woodlands and which is also a useful fuel when abundant. Whereas the Stipa and Aristida fuels are essentially ephemeral in nature, at best lasting only 2 seasons in any abundance, the spinifex fuels are ling-lived. 

Advantages of burning: Woody weed control, hazard reduction, coppice reduction, stimulation of herbage growth and species diversity.

Disadvantages of burning: erosion, loss of forage, loss of timber, increase in woody weeds & undesirable herbs, losses to beekeepers.

Conclusions: The dominant role of grass fuels in most rangeland ecosystems appears to have been only partially recognised. This requires better consideration.


Abstract: Among the most popular media images of Australia are the outback heroes: the explorer, pioneer and pastoralist. However, there is insufficient attention paid to the role that pastoralists and their management strategies have played in the dispossession and degradation of arid Australia. A historical overview of ecology and land management suggests that the fragility of Australia's arid ecosystems was identified over 100 years ago, and despite repeated calls for reform, effective regional management schemes are still vehemently opposed by pastoralists. I argue that, until the role played by pastoralists and their management strategies in the degradation of arid Australia has been adequately communicated, pastoralists will remain a powerful political lobby capable of thwarting the implementation of sustainable land management practises.
Notes: Impact of pastoralism in arid Australia - initially their strategy was to maintain herds during droughts that could breed and be sold after high rainfall seasons which would stress the vegetation and soils around natural waterholes. After 1920 artesian bores could be constructed easily, dependence on natural waters reduced and higher stocking rates persisted particularly during droughts - degradation. Stocking rates collapsed with drought despite the presence of bores and rabbits were also blamed for this collapse but there is considerable evidence that it was stock and not rabbits that were the primary agent of degradation (Radcliffe 1947). The elimination of perennial plants (soil binding & water retention) led to soil erosion which transformed the land surface. This 'desertification' has been widespread throughout the world's arid areas. Many animals have become extinct in the arid zone, especially within the last 50 years. No one factor has affected the entire arid zone to cause these extinctions so they are likely to be a response to a number of factors in combination particularly stock and introduced predators


Abstract: Patch-burning is frequently advocated as a management tool to enhance the biodiversity and pasture values of spinifex (*Triodia*) grasslands. In the northern Simpson Desert, Queensland, pastoralists use fire to reduce the likelihood of broad-scale wildfires and improve pastures for cattle. I conducted a before–after–control–impact experiment to investigate the response of small mammals to the short-term (<1 year) effects of patch-burning between August 1999 and June 2001. The experiment was replicated at three locations subject to differing rainfalls, with two 1-ha study grids remaining unburnt as controls, and two being burnt at each location. The areas burnt ranged from 1 to 3 ha. *Dasycercus cristicauda* and *Pseudomys desertor* responded negatively to the fire treatment. *Notomys alexis* responded positively to the fire treatment in the final trapping session but only at one location. Factors indicative of temporal and spatial variation in rainfall, time and site had a greater effect on the abundance of small mammals than the fire treatment. Heavy rainfalls in 2000 increased seed production and prompted increases in the populations of rodent species and *Dasycercus cristicauda*. The greatest numbers of captures were made at the sites that received the highest rainfalls. Patch-burning regimes are likely to increase the resilience of 'fire-sensitive' species dependent on dense spinifex by reducing the extent of wildfires.


Abstract: Since European settlement there have been profound changes to the fauna of semi-arid and arid Australia. Some species have gone extinct, others have become rare or
restricted in range and some have increased their range and abundance. Many, but not all of
these changes in species range and abundance have been linked to the direct and indirect
impacts of pastoralism. Grazing by livestock is the main 'direct' impact of pastoral activity and
has resulted in widespread changes in habitat structure and a decrease in primary
productivity. The loss in primary productivity may have reduced the capacity of the landscape
to support some fauna species. Pastoral activities have also had indirect impacts on fauna
through the establishment of pastoral infrastructure such as artificial water and barrier fences,
and pest control activities. These indirect activities have caused some species to increase in
abundance and others to decrease. The widespread extinction of dingoes is likely to have
exacerbated the impacts of foxes and overgrazing. Successful restoration of the arid zone
fauna will require the restoration of ecological functions and species interactions, particularly
nutrient cycling and predation.


Notes: Climate is probably the key environmental factor in establishing the characteristics of
the fire regime.
Climate variability: SOI, ENSO, fire prediction modelling
Climate change: We are moving into a period of increased interannual variability and an
increase in mean global temperature producing greater likelihood of extreme weather events.

Management of Australia's Rangelands (eds G. N. Harrington, A. D. Wilson and M.

Abstract: Contents: Geographic; Characteristics of the Vegetation; Pastoralism;
Administration; Conservation Issues


Abstract: SHRUBKILL is a microcomputer based decision-support system which provides
expert advice on the use of fire to control non-desirable shrubs and thus improve grazing
potential in the semi-arid woodlands of eastern Australia. Prescribed fire is argued to be the
only economically viable management option for broad-scale shrub control in these
rangelands. Management decisions about "when" and "how" to bum and the cost and
expected economic benefit of buming involve answering many difficult questions which can
be aided by the advice of experts. However, these experts are not always available to give on-
the-spot advice to managers. SHRUBKILL is a decision-support system that has incorporated
the knowledge of fire-experts in an easy-to-use microcomputer program to: advise the user on
what the “expert” would have recommended; provide detailed information supporting the
expert’s recommendation; and give summaries of the consultation. SHRUBKILL was written in
BASIC on an IBM Personal Computer but it will run on IBM PC compatibles.

Ludwig J. A. (1998) Ten years on, created landscape patches are still functioning. Range

**Abstract:** In Aug 1988, piles of mulga (*Acacia aneura*) branches were used to test
experimentally whether vegetation patches could be recreated on slopes made barren by a
grazing trial. The experiment was designed to verify the proposition that by consistently
concentrating scarce resources onto a patch, soil properties would be markedly improved,
favouring the establishment of perennial grasses. This experiment, conducted on Lake Mere
Station, NSW, was monitored each spring, summer, autumn and winter season until 1991.
After this 3 year period the branch-treated plots had greatly improved physical, chemical and
biological soil properties and supported healthy populations of perennial grasses, especially
compared to the experimental plots without mulga branches. These experimental results
were reported in two papers (Ludwig & Tongway 1996; Tongway & Ludwig 1996). After 1991,
the experimental plots were monitored each spring until 1995 and then again in Aug 1998. In
this article we report that after 10 years, the mulga branch plots were still functioning as fertile
patches. This is evident from their ability to produce a burst of plant growth following removal
of grazing in 1997 and good rains in the summer and autumn of 1998. This 'good seasons'
burst was not evident in non-patch plots, which (except for ephemerals) remained about as
bare as after the 1991-1995 drought.

**Notes:** Restoration of productivity in over-utilised rangelands is difficult - economically and
other factors. A wide variety of restoration techniques have been tested - mechanical,
chemical, biological, blade ploughing, herbicides and reseeding often in combination didn’t
result in rehabilitated rangeland in the longer term. Rangelands often described as patchy
with vegetation-soil zones are east to detect; many grassy rangelands, especially those on
heavy clay or very sandy soils tend not to be patchy but many woodland and savanna
rangelands on crusted clay-loam, red-earth soils are patchy, especially in areas with low erratic
rainfalls and on gentle topography. The landscape function approach suggests that
rehabilitation will be achieved by rebuilding patches which serve to capture and retain soil
water and nutrients in runoff, and organic matter in wind-borne litter, rather than have these
vital resources lost from the system. Topography of study sites - gently undulating with low
stony ridges and gentle slopes (<0.5%) extending onto weakly dendritic drainage lines (not
incised). Mulga vegetation strongly patterned into groves and intergrove patches. Aim of
experiment was to recreate fertile patches similar to those that occur naturally in mulga
woodlands.

*After 3 years:* Mulga piles trapped sediments while those with no branches lost 0.9mm/year of
soil - important since most nutrients e.g. available nitrogen, occur in the top few centimetres
of the soil in many rangelands; water infiltration rates were 10x higher within branch patches;
soil invertebrates increased with ants and termites forming biopores which enhanced water
infiltration; soil respiration was 10x greater within patches due to greater biological activity; fertility 3x greater with organic nitrogen and carbon significantly greater in the top few centimetres of soil in patches; cation exchange capacity and electrical conductivity also significantly greater in patches. From 1986-1990 perennial grasses, forbs & sub-shrubs established and grew strongly under branches.

After 10 years: Mulga Mitchell grass - even after good seasons and without grazing only increased in cover by 1% without mulga branches but increased 9% with branches; Mulga Oats, Woollybutt and silky bluebush cover also increased significantly more within branch patches. Mulga branch piles still functioning to trap sediments and water after 10 years. These resource-rich patches enable perennial plants and other organisms to survive through droughts and TGP so that when good rains come recovery is rapid. Regrowth is not as evident outside these patches and tends to be limited to plants adapted to establishing on hard infertile soil patches.

These small patches (10m sq) are robust and after 10 years still functioning and branches cut as feed, if placed appropriately along contours could serve this function. A larger response could also be obtained by chaining in strips along contours, leading to enhanced regrowth of perennial grasses.


**Abstract:** Past and current research on restoring degraded rangelands was reviewed at a workshop held in July 1989 by the CSIRO Division of Wildlife and Ecology. Basic ecological and economic principles for restoration, and prevention of further degradation, were explored and priorities for future research were identified. Although all ecological principles are applicable to restoring degraded rangelands to some degree, four principles emerged as being critically important: (1) ecesis, those basic processes involved in the successful establishment of desired forage species; (2) ecological succession, that series of species replacements where fast growing ephemeral species are replaced by slower growing perennial species which are strongly competitive; (3) resource patchiness, where resources, such as nutrients and water, are concentrated within patches or islands; and (4) facilitation, where herbivores (e.g. kangaroos) act as agents for seed dispersal, influence the establishment of seedlings, and shift species composition by causing differential mortality in species populations. A number of economic principles also apply to the restoration of rangelands. However, one very significant principle emerged from the Workshop: sustainability, which implies that economic benefits must be long-term, cumulative and lasting (i.e. the costs and benefits of restoration treatments must be viewed well into the future). Participants in the Workshop listed the following research areas as high priority: (1) assess the extent and current rate of degradation in different rangeland regions, (2) define indicators of degradation for different rangeland types, (3) form multi-disciplinary teams to study those processes critical to understanding degradation and restoration (include scientists from different organizations such as CSIRO and State agencies), and (4) transfer information to land managers to raise their awareness of the degradation problem and the need for restoration using appropriate tools such as computer-
based decision support systems (including economic models).

Notes: Summary of results of workshop re rangeland degradation.


Abstract: Fire is a potent force; its impact must be included as a key element in management plans for mallee conservation areas. For many management objectives wildfires can be devastating. However, prescribed fire can be used as an effective tool for mitigation of wildfire and for enhancement of landscape diversity. Managers wish, therefore to understand the conditions under which fire should be included or excluded to meet management objectives. The structure and operation of a microcomputer-based 'expert system' - MALLEEFIRES - is described. This system is designed to provide advice on the use of prescribed fire in mallee reserves. It utilises published research results and unpublished data held by 'experts' on the use of fire in mallee but generally not accessible for managers. MALLEEFIRES is structured as 3 modules providing management advice for decision-making relative to fire danger conditions, operational procedures and economic impacts of fire management in mallee reserves.


Abstract: The spatial organisation of three major landscape types within the semi-arid woodlands of eastern Australia was studied by a detailed analysis of gradient-oriented transects (gradsects). The aim was to characterise the spatial organisation of each landscape, and to account for that organisation in functional terms related to the differential concentration of scarce resources by identifiable processes. Terrain, vegetation and soils data were collected along each gradsect. Boundary analysis was used to identify the types of landscape units at a range of scales. Soil analyses were used to determine the degree of differential concentration of nutrients within these units, and to infer the role of fluvial and aeolian processes in maintaining them. All three major landscape systems were found to be highly organised systems with distinctive resource-rich units or patches separated by more open, resource-poor zones. At the largest scale, distinct groves of trees were separated by open intergroves. At smaller-scales, individual trees, large shrubs, clumps of shrubs, fallen logs and clumps of grasses constituted discrete patches dispersed across the landscape. Our soil analyses confirmed that these patches act as sinks by filtering and concentrating nutrients lost from source areas (e.g., intergroves). We suggest that fluvial runoff-runon and aeolian saltation-deposition are the physical processes involved in these concentration effects, and in building and maintaining patches; biological activities also maintain patches. This organisation of patches as dispersed resource filters (at different scales) has the overall
function of conserving limited resources within semi-arid landscape systems. Understanding the role of landscape patchiness in conserving scarce resources has important implications for managing these landscapes for sustainable land use, and for the rehabilitation of landscapes already degraded.

Notes: Mulga grove-intergroves on stony ridges and slopes with reddish clay loams (hard red earths). Landscape organisation is ascribed to runoff/runon processes in eastern and central Australia as well as in the Serengeti of east Africa and the Chihuahuan desert of Mexico. In arid/semi-arid environments runoff/runon concentrate scarce water and nutrient resources from source areas to sinks. Landscape viewed as being comprised of a series of resource sinks at different scales - groves, shrub mounds, grass clumps - separated by source areas and being connected by the flow of water and nutrients from the top of the landscape to the bottom. Found patches of grove / intergrove at the larges scale and within intergroves shrubs, fallen logs, grass clumps also formed sink patches.

Landscapes in the semi-arid woodlands of eastern Australia are organised into a source-sink system. Tree groves can be mulga, rosewood, ironwood, gidgee or box and are sinks rich in resources. N & C concentrated there. Smaller scale landscape patches also function as resource traps or sinks. At the smallest scale grass clumps operate as individual tussocks or as tussock clumps entrap windborne materials including litter fragments and soil particles to form accretion mounds. These play a vital role in creating a micro-habitat where soil aeration and infiltration are improved and soil nitrogen is maintained at higher concentrations. Sustainable maintenance of semi-arid landscapes requires an understanding of the dynamics of the landscape processes involved in maintaining patchiness and how processes are altered by degradation.


Abstract: This paper describes a practical technique, tested experimentally, for rehabilitating degraded semiarid landscapes in Australia. This rehabilitation technique is based on the ecological principle that semiarid landscapes are spatially organized as patchy, source-sink systems; this patchy organization functions to conserve limited water and nutrients within the system. The aim was to rebuild vegetation patchiness, lost through decades of utilization of these landscapes as rangelands. Patches were reconstructed from large tree branches and shrubs obtained locally and placed in elongated piles along contours. These piles of branches were very effective in recreating productive soil patches within the landscape, as described in part I of this study (Tongway & Ludwig 1996). These new patchy habitats promoted the establishment and growth of perennial grasses. Although the foliage cover of these grasses declined into a drought, which started before the end of the experiment, plant survivorship remained high. This suggests that patches also function as refugia for organisms during droughts. The patches of branches remained robust and functional, even under grazing impacts, although plant growth and survival were significantly higher within an ungrazed paddock than in a grazed paddock.
Notes: Desertification has converted many areas within the once open grassy savanna-like parklands into areas of dense shrubs, ephemerals or base soils. Mechanical means have been tried to reverse this situation but this has been only partially successful and very expensive to implement. Dense shrubs can also be controlled effectively with fire but opportunities to use prescribed fire are restricted to rare high-fuel years. It is essential to know what ecosystem processes have been disturbed before rehabilitation procedures and treatments for restoration can be designed. Landscape systems are highly organised with distinct resource-rich patches separated by more open resource-poor interpatch areas. This landscape heterogeneity is maintained by water-driven (fluvial) runoff-run-on, erosion-deposition processes and wind-driven (aeolian) saltation-deposition processes. These processes concentrate limited resources (water & nutrients) from source areas into sinks or patches. Patches act as resource filters and conserve limited resources within the semi-arid landscape. Branch patches created for the experiment enabled a favourable response in non drought times, in both grazed and non grazed paddocks. Vegetation is restored in degraded landscapes by the creation of landscape patches due to the improved productive potential of the soil within these patches. C3, C4 grasses, subshrubs and shrubs all responded favourably. Addition of fertilizer or litter alone did not produce the same response. The construction of fertile patches with piles of branches that are robust to weathering and grazing can become part of an ongoing land management strategy. Foliage cover of perennial grasses declined to near zero during the drought but they continued to survive in fertile patches even during prolonged drought.


Abstract: Functional integrity is the intactness of soil and native vegetation patterns and the processes that maintain these patterns. In Australia's rangelands, the integrity of these patterns and processes have been modified by clearing, grazing and fire. Intuitively, biodiversity should be strongly related to functional integrity; that is, landscapes with high functional integrity should maintain biodiversity, and altered, less functional landscapes may lose some biodiversity, defined here as the variety and abundance of the plants, animals and microorganisms of concern. Simple indicators of biodiversity and functional integrity are needed that can be monitored at a range of scales, from fine to coarse. In the present paper, we use examples, primarily from published work on Australia's rangeland, to document that at finer patch and hillslope scales several indicators of landscape functional integrity have been identified. These indicators, based on the quantity and quality of vegetation patches and interpatch zones, are related to biodiversity. For example, a decrease in the cover and width (quantity) and condition (quality) of vegetation patches, and an increase in bare soil (quantity of interpatch) near cattle watering points in a paddock are significantly related to declines in plant and grasshopper diversity. These vegetation patch-cover and bare-soil indicators have been monitored traditionally by field-based methods, but new high-resolution, remote-
sensing imagery can be used in specific rangeland areas for this fine-scale monitoring. At intermediate paddock and small watershed scales, indicators that can be derived from medium-resolution remote-sensing are also needed for efficient monitoring of rangeland condition (i.e. functional integrity) and biodiversity. For example, 30–100-m-pixel Landsat imagery has been used to assess the condition of rangelands along grazing gradients extending from watering-points. The variety and abundance of key taxa have been related to these gradients (the Biograze project). At still larger region and catchment scales, indicators of rangeland functional integrity can also be monitored by coarse-resolution remote-sensing and related to biodiversity. For example, the extent and greenness (condition) of different regional landscapes have been monitored with 1-km-pixel satellite imagery. This regional information becomes more valuable when it indicates differences as a result of land management. Finally, we discuss potential future developments that could improve proposed indicators of landscape functional integrity and biodiversity, thereby improving our ability to monitor rangelands effectively.

**Notes:** Rangelands have been subdivided into bioregions that reflect their value for pastoral use and susceptibility for damage. Pastoral damage takes many forms but one impact is the loss of landscape functional integrity - intactness of natural vegetation and soil structural patterns and the processes that maintain these patterns. Basic landscape patterns and processes need to be maintained at all spatial scales, from fine to coarse. Healthy landscapes retain water, soils, nutrients, and organic matter in a network of patches on hill slopes within paddocks, within watersheds on properties and within regional catchments. Landscapes are composed of 2 or more land units positioned so that they are functionally linked by source-sink processes (e.g. run-off/run-on) which can vary from finer hillslope scales to coarser watershed scales. During large rainfall events there are large flows of water and materials down hillslopes and out of catchments but there is concern when these flows become excessive due to unhealthy landscapes. We need to improve our understanding of the links between landscape function and biotic populations over a hierarchy of scales - hillslope patches to regional catchments. Examples used include the mulga log mounds, tall tussocks as obstructions on hillslopes in cleared eucalypt woodlands. Biograze: found that understorey plants and birds are more efficient indicators of grazing impacts than invertebrates. The closer the spacing of shrubs (e.g. Bluebushes) the less likely resources will leak from the landscape. Indicators of landscape functional integrity: vegetation patch quantity and quality (cover and condition) - reflect the potential of a landscape to retain, not leak vital water and nutrient resources.

Rangelands can be restored by building vegetation patches that function to retain resources on hillslopes or at the base of hillslopes but a broader landscape view is also needed, encompassing geomorphic and hydrological processes. Scale is important because a landscape may appear to be intact or to have functional integrity at a fine scale but overall it may be degrading when viewed at a large-scale.

Abstract: The expansion of the afromontane forest community in Orange Kloof, Table Mountain, between 1933 and 1990 was measured using aerial photography. The study area is unique because it has been protected from fire since 1933, allowing forest to expand into the adjacent Cape fynbos communities. The area of forest has doubled after 55 years of fire protection.

Notes: Fynbos is a heathland community. Forest originally destroyed within the first 50 years of settlement in 1652. There was a significant increase in forest cover between 1933 & 1990. The heath and forest are considered to be seral stages.


Abstract: A 2-year study was conducted to investigate two aspects of the local distribution of the Rufous hare-wallaby, *Lagorchestes hirsutus*, in a region of the Tanami Desert. These were: (a) patterns of habitat use in response to changing environmental conditions and (b) environmental parameters influencing 'local' choice of habitat. Counts of faecal pellets and tracks were used to obtain indices of hare-wallaby activity within occupied sites and to gain an insight into the movements by individuals. Local choice of habitat was analysed by assessment of numerous habitat features at occupied and unoccupied sites in the region. Previous surveys over the greater part of the study area provide evidence of a significant local decline and local contraction of range by *L. hirsutus* during recent times. Hare-wallabies showed seasonal trends in the relative use of different vegetation systems in response to the relative availability of food items within each habitat. The home ranges of hare-wallabies consisted of two distinct areas of activity: a large sparsely used area within the dense Triodia pungens vegetation and a small concentrated feeding area within the neighbouring caliche system. Hare-wallabies were dependent upon a specialised form of spinifex habitat. Patchiness, hummock size, food diversity and the degree of floral senescence affected suitability for hare-wallabies. Within the Tanami Desert site, suitable combinations of these characters were associated with tight mosaics of different regenerative stages after fire. Fire is therefore clearly implicated as an important force in creating a greater diversity of feeding and sheltering habitats for the hare-wallabies in the otherwise uniform spinifex sandplains. There is an obvious role for the application of controlled burns as a means of managing habitats to favour *L. hirsutus* in the Tanami Desert.

Abstract: The Pigfooted Bandicoot, discovered on the plains of the Murray in 1836, was scarce by 1857 when its demise was predicted because of the large flocks of sheep and herds of cattle that were occupying the country. In 1901 a Royal Commission reported on the economic plight of the pastoralists and recorded eyewitness accounts of the degradation of the western lands from drought, rabbits and erosion exacerbating the impact of overstocking with sheep. In 1983-84 a Joint Select Committee of the Parliament of New South Wales presented four reports detailing the problems and issues of the pastoral industry and the environment in the Western Division. In 1991 the Ecologically Sustainable working group of the Commonwealth Government tabled its final report on Agriculture, drew attention to the major environmental issues and urged taking a longterm ecological view of land management. In 1992-93, CALM, the New South Wales department with the responsibility for managing the Western Division, produced two reports concluding that the Western Division pastoral industry and the land resource supporting it were in crisis. Against the background of these official views, some contemporary writing by ecologists and the primary themes of the book are foreshadowed. Central among these are the need for further research, including survey, of the fauna; the need for a representative reserve network and the necessity for a longterm goal of restoration. To conserve the fauna of western NSW it will be necessary to move fauna conservation to a key position in any research and management programme. The recovery of the fauna serves as an indicator of success in any restoration endeavours.

Notes: Royal Commission of 1901: Describes soil and vegetation changes between 1880 to 1901 from observations of landholders and stock inspectors eg 'The country was more or less eaten out. We all over-estimated the capacity of the country. I have had a large experience, over forty years north of the Murray, and we have only just learnt that the country will not recover, and cannot be occupied with the same advantage as it was before.' E. Quinn Tarella near Wilcannia. There has been little further change in the ensuing 100 years.

Joint select Committee of the parliament of NSW 1983-4: History of the Western Division - Appendix 3 - at the time Oxley, Mitchell & Sturt opened up the western division (1817-46) there were 13 tribal groups.

From the evidence presented to the royal commission of 1901 it seems to Lunney that the drought in the late 1890s had a far worse impact than earlier droughts because the vegetation had been stripped away by overstocking.


Abstract: This chapter summarises the Royal Commission of 1901 into the western lands of New South Wales. The procedure adopted was the use of quotations to preserve the emphasis and colour of those who bore witness to the rapid changes induced by overstocking with sheep, and from rabbits, drought and erosion. The selection presented here reflects what emerged as most relevant during the period of editing Future of the Fauna of Western New

Abstract: Twenty-four mammal species – predominantly the medium-sized, ground-dwelling mammals with a dependence on grass/herbs and seeds – disappeared forever from the landscape of the Western Division of New South Wales in a period of 60 years from first settlement in 1841. The present study examines the causes of this extinction episode by constructing a picture of the changing landscape from the historical record and interpreting the findings ecologically. The conclusions point to an extinction process that can be largely attributed to the impact of sheep, an impact that was exacerbated in the scarce and fragile refuges of the flat landscape in times of intense and frequent drought. This conclusion differs from those of many others, particularly Kerin in the Western Lands Review, who pointed to "the impact of feral animals, rather than overgrazing" as the cause of mammal extinctions, and Morton, who considered that the rabbit was "principally (although not entirely)" responsible for mammal extinctions in the rangelands. The rabbit plague in the Western Division from the early 1880s and the influx of foxes in the last years of the 19th century expedited the local demise of some species and even delivered the final blow to surviving remnant populations of a few species of native mammals but they were not the primary agent of extinction. Historical accounts give prominence to the rapidly growing wool industry in the 19th century. From its dominant position as an export commodity, wool became the chief means of the successful spread of colonial settlement. By 1853 there were about 300,000 sheep based at the southern end of the Darling on the watered frontages, which were all taken up by 1858. The west of the Darling was largely occupied by sheep farmers between 1859 and 1876. The history of settlement around Menindee from 1841 can be read as a devastating critique of the failure to realise that the west could not sustain a pattern of land use imposed on it from another world. The deterioration of the pastoral landscape was such that by the late 1880s the "walls of the pastoral fortresses... were beginning to crumble of their own accord, as the foundations on which they were built — the physical environment — altered under stresses...". The sequence of occupation and land use in the Western Division and the timing of the loss of native mammal species allows the conclusion to be drawn that it was sheep, and the way the land was managed for the export wool industry, that drove so many of the mammal species to extinction. The impact of ever-increasing millions of sheep on all frontages, through all the refuges, and across all the landscape by the mid 1880s is the primary cause of the greatest period of mammal extinction in Australia in modern times.

Notes: Analysis of historical records to determine the reason for the loss of 24 mammal species in a space of 60 years. The Western Division supported 100% of the 11-100g mammals, 88% of 101-1000g mammals & 89% of 1001-5000g mammals + many of the threatened species 11-100g are found in this region. General conclusion: the heavy ecological footprint left by the English wool industry which drove land use, sheep numbers and the way the land was
managed in the NSW Western Division in the 19th century irrespective of the particular conditions of the fragile, drought prone region of the Aust rangelands.


Abstract: The major weed problem facing the pastoral industry of western New South Wales is the wide scale degradation of native pastures via encroachment of non-desirable native shrub species - so-called 'woody weeds' (e.g. Turpentine, Budda, Punty, Hopbush, Mulga, etc). The shrub encroaching problem has increased in severity since the early decades of the present century and has been largely attributed to removal of perennial grass species by extended periods of overgrazing and changed fire regimes. Shrub encroachment leads to large scale economic losses through reduced levels of animal productivity, increased flock mortality rates, more difficult stock handling and management and reduced property capital values. The paper discusses the nature and extent of the shrub encroachment problem and enumerates the economic cost to the industry at both the property and regional level. It is estimated that a typical property experiencing a serious shrub encroachment problem could suffer a potential income loss of approximately $40,000 per year. The annual income loss to the pastoral industry in western New South Wales is estimated to be of the order of $25.5 million.

Notes: Estimates based on the gross margin per dry sheep equivalent (g.m./d.s.e.) - the difference between total receipts (gross income) and direct running expenses (variable costs). Data presented as single line graphs without sample size or standard errors. The analysis indicates the potential magnitude of licence and capital losses to the wool and sheep industry in western NSW by shrub encroachment.

Abstract: Statements concerning rangeland degradation and restoration issues are often supported by technically oriented evaluations, with limited consideration of the economic implications of resource conservation or rehabilitation. In the few cases where an attempt has been made to incorporate economic elements into analyses, some shortcomings have been evident in the methodology adopted. This has sometimes produced misleading results, and has made comparisons of different restoration technologies difficult. This paper examines several issues that are important in obtaining an economic perspective on the restoration of degraded rangelands. The formal procedure of benefit-cost analysis is presented as a rational framework for the economic evaluation of such activities. The framework is applied, via a case study approach, to examine the private economic value of several technologies for rangeland restoration. However, because the analysis is based on limited data, the conclusion is indicative rather than definitive. Issues relevant to the extension of the analysis to encompass social evaluations of rangeland restoration management are canvassed.


Abstract: The Australian Rangeland Society represents a coordinated body of people who have a common interest in the rangelands. Currently that interest base is widening as we witness the emergence of multiple use values and multiple stewardship in the rangelands of the world. This move towards multiple use requires all stakeholders to recognise and understand the cultural, social, and economic values of others and to actively seek landuse patterns which are congruent with all stakeholder values.

Notes: General descriptions, definitions and issues provided -
Rangeland stakeholders: pastoralists, miners, aboriginal people, tourists and operators, alternative land users, conservationists, urban community, global community.
Environmental activities & issues: biodiversity, land degradation, pest animals, global warming, pastoralism, mining, tourism
Commercial activities and issues: pastoralism, mining, tourism, alternatives.
People in Rangelands: employment and population education and health, Aboriginal people
Global activities and issues
Maher M. (1995) A thin line: Should densities of Coolibah and Black Box be controlled in the Western Division of New South Wales. NSW Department of Conservation and Land Management.

Abstract: This report discusses the distinction between clearing and thinning of coolibah and black box vegetation in parts of the Western Division. Includes discussion of the values of coolibah and black box woodlands for grazing, nature conservation, culture, river health and global climates, the ecological processes on the floodplains (flooding, grazing, fire) and the sensitivity of these woodlands to disturbance (floods, droughts and climate change, clearing, grazing and fire). Provides a natural thinning curve demonstrating that after 100 years less than 3% of a flood germinated cohort will survive.

Notes: The role of fire in floodplain ecosystems is unknown. There have been wildfires since pastoralism - the large coolibahs carry fire scars. There is strong anecdotal evidence to suggest that fire was used as a management tool. Asks the questions: 'Is there a role for fire on grazing leases? Are properties large enough to allow pasture to be used for fuel? What were the burning patterns pre-pastoralism? Can enough fuel be produced in the denser woody areas?'


Abstract: Landscapes of the Ledknapper Spinifex: part of an extensive drainage system between the Warrego, Culgoa and Darling Rivers. First settled 1859. Learnt to stock this land conservatively. Controlled burning, wildfire and stocking have all had an influence on today's spinifex country but the actual effect of those influences is debated. Observers of the area during the 1930s reported thousands of acres of pure spinifex with virtually no scrub at all. Today the same areas are infested with 'woody weeds' while adjacent areas are free. Some argue that burning increases the incidence of woody weeds while others seek to burn more frequently believing that it will provide greater grazing value from the young spinifex. Landholder (M Robertson) observations: If allowed to grow unmanaged spinifex becomes too thick for other plant species to survive, limiting grazing potential. After the old clumps have been burnt other grasses and herbages (including parakeelya) grow. Given an average run of seasons with some summer rain, 4 or 5 years of grazing is available before the reestablished spinifex clumps begin to dominate. After a successful burn and in a good season this country can be used for weaner sheep, cattle or lambing ewes. It is generally accepted that burning increases the incidence and density of the problem shrubs. Time of burn, rainfall before and after, stocking pressure and burn frequency all influence the outcome. Controlled burns give the manager options that wildfires take away. There is a cycle of 7/8 years from a new clump to burnable clump - the decision to burn a prescribed area of the spinifex on a rotational basis provides a balanced mixture of plant generations and pasture conditions. Need to have fire breaks to protect property given the fierce nature of spinifex fires. Discusses approaches,

**Abstract:**
Notes: Booklet describing the history of the Gunderbooka Range and surrounding lands. This includes the Aboriginal history, pastoralism, the conditions through the first half of the 20th century, woody weeds, fire, rainfall, declaration of the National Park.


In western NSW Aboriginal land management practices ceased with the invasion of European pastoralists a century and a half ago.

European explorers crossed open grasslands punctuated by scrub around Gunderbooka Range. Charles Sturt 1828 - after passing through a dense mulga scrub - 'but on clearing it we were amply repaid for all previous troubles. The hill which we had occasionally seen, broke full upon us, at a distance of about two miles and a half, the intervening space being a continued meadow, of singular equality of surface while the grass was up to the horse's middles as we rode thro it.' Mitchell in 1835 described a plain 'covered by a half burnt scrub'. From the highest point on the range he looked south to Dunlop's range to see a 'long line of smoke skirting its northern base. In the late 19thC Grenville Teulon recorded that Bourke Aborigines used the word 'pullara' to denote both open country and flame. Paarkintji elder Bill Elwood - ancestors camped 'in winter time out of the wind ..... around the side of the hill ... in summer time most of the big families would go back to the Darling River where there was plenty of water and just before the summer started they would burn it all off, and when they came back in the winter they would have a good crop of everything growing, they used to burn everything off.' Discusses the ravages of small pox and violent killing of the aboriginal people with quotes from the time. 'Retribution' massacres of the people.

Pastoralism: In 1874 with no fencing or tank sinking on Yanda Station near Gunderbooka, sheep grazed the back country for short periods after rain and in its unimproved state the station could only carry 5000 sheep. In 1882 after much fencing and tank excavation 106,200 sheep grazed Yanda's paddocks. Drain lines, some over 10 km long snaked across each paddock guiding runoff into tanks. And made little impression on the 'pasture that grew'. Before pastoralism spread out from the Darling River great fires swept the grassy back country. A correspondent visiting the Darling backblocks witnessed numerous bushfires which threatened to destroy the whole district. While the bushfires were beaten off the occupied country local pastoralists didn't control the fire on the unoccupied country where the grass was 6 feet high.

Local descriptions of spread of woody shrubs on properties around the Gunderbooka area. Also the change in vegetation caused by the rabbit invasion. 'Although 25 inches of rain fell in 1891 no grass grew. Edible scrubs were being destroyed by rabbits, and sheep were starving. The ground was saturated with moisture, which produces a green moss only, which perished off with the first dry spell.' Cats were bred and released to control rabbits.
It is considered that 3 to 6 inches of soil have been lost from hundreds of thousands of acres in the Cobar district (interdepartmental committee 1969). After the dust storms, when rain did fall the exposed over-trodden earth readily washed away Details the harsh life and conditions in the 1930s and 1940s. Dingo numbers grew in the 1920s 1930s - suggests that they kept goats and kangaroos in check. Suggests that the problem with 'woody weeds' really took off in 1950s in Gunderbooka area, and with the replacement of the open landscape, populations of pigs, goats and foxes took off. Few trees present in records from the 1930s and 1940s when there were also fierce dust storms. New land management approach also took hold in the 1950s with the boom in wool prices: introduction of more watering points, subdivided leases into smaller paddocks and raised stocking rates - but loss of productivity caused by woody weeds caused sheep numbers in the Bourke Cobar area to drop by a third. Feral animals population growth - pigs - in 1979 WLC reported that pigs took $20 million worth of lambs, 1990, shooters removed 5000 pigs from the Bourke district; goats - 1990, Burrawa's hills heavily infested with goats but they were known to live on and around Gunderbooka for much longer than that but droughts of the 1930s and 1940s restricted the goat population, numbers shot up after WWII due to run of good seasons and increasing cover of scrub.


**Notes:** Early records from many areas of Australia indicate that at the time of European settlement soils were soft, crumbly and friable. It has long been assumed that the hoof action of domestic stock was the principle cause of the ground becoming less hard and capped. But the deterioration of soil health also coincided with the dramatic decline or complete extinction of many small native mammals and the consequent cessation of the soil disturbances and interactions that they created. Early soil descriptions were very different - e.g. James Cotton Royal Commission 1901. The transformation to hard red soils was regarded by some as necessary for a profitable pastoral production. Rainfall infiltrated into soft spongy soil - ran off and filled tanks and waterholes from hard soils increasing carrying capacity. Unfortunately this also meant that the soil humus, microorganisms and plant-available nutrients lead to its impoverishment. Healthy soils interact with large and small animals, plants, invertebrates and microorganisms, nutrients, structure, organic matter and soil organisms. Soil formation should be an ongoing process (aggrading soils). Discusses the activity by small mammals that manipulated the soil and kept it healthy and control of ground cover so reducing fire intensity and frequency. Movements crated a patch dynamics. Led to high levels of organic matter and microbial activity, a balances water cycle and species rich healthy rangelands. Describes: digging behaviour of medium sized mammals - soil disturbance regimes; the importance of microbes for soil fertility; water repellent soils.

**Abstract:** Fire-driven succession and a period of high rainfall had a pronounced effect on the distribution and abundance of small mammals inhabiting spinifex grassland in Uluru National Park from 1987 to 1990. Species richness and abundance were generally higher on sites burnt in 1976, where six species (*Pseudomys hermannsburgensis*, *Pseudomys desertor*, *Mus domesticus*, *Dasycercus cristicauda*, *Ningaui ridei* and *Sminthopsis youngsoni*) were caught more frequently. Two species (*Notomys alexis* and *Sminthopsis hirtipes*) were more abundant on sites burnt in 1986. Murid rodent numbers fluctuated substantially following high rainfall. The number of individuals increased 100-fold, and species richness increased from two to four when *P. desertor* and *M. domesticus* appeared in the second year of the study. In contrast, captures of dasyurid marsupials increased only slightly over the three years, with the most dramatic increase occurring for *D. cristicauda*. This study highlights the importance of fire as a management tool. Patch burning within spinifex grasslands maximises species diversity of small mammals by ensuring that suitable successional states are present at all times. This is particularly important for species that are restricted in their distribution, such as *D. cristicauda*.


**Abstract:** Fire-driven succession had a pronounced effect on the distribution and abundance of reptiles inhabiting spinifex grasslands in Uluru National Park from 1987 to 1990. Forty species of reptiles were trapped during the study. Of these 14 were common (> 20 captures), 6 were uncommon (11-20 captures) and 20 were rare (< 10 captures). Species richness and abundance of individuals were greater on plots with mature spinifex for most species. On most sampling occasions only four geographically widely distributed species were more abundant on the regenerating plots: *Rhynchoedura ornata*, *Diplodactylus stenodactylus*, *Ctenophorus nuchalis* and *Ranphytophlops endoterus*. Two species, *Diplodactylus conspicillatus* and *Lerista bipes*, showed no significant difference in abundance between plots. This study supports the suggestion that fire mosaics maximise reptile diversity. Although most reptile species were caught in mature spinifex, regenerating areas act as fire breaks and ensure that mature spinifex is always present.

Abstract: In the semiarid Mulga Lands of southern Queensland soil nitrogen (N) levels have declined after clearance of the native mulga (Acacia aneura F. Muell. ex Benth.) and conversion to grazed buffel grass (Cenchrus ciliaris) pasture. At three mulga sites, declines in soil total N ranged from 14% to 28% in the surface 10 cm of soil. In situ net N mineralization from December 2003 until November 2004 in the surface 10 cm was 49.5 kg N per ha per year in the mulga woodland, 48.2 kg N per ha per year in the young (<5 years old) buffel pasture (previously sown to wheat (Triticum aestivum L.) and 34.6 kg N per ha per year in the old buffel pasture (>20 years). Ammonium-N was the dominant N pool under mulga in the top 30 cm, while nitrate-N was dominant under the buffel pastures. Although ammonium-N under mulga was significantly different to that for 21-year-old buffel pasture at all depths, nitrification and net N mineralization were not different between the three land uses at any depth or in the entire 90 cm profile. The Soil Nitrogen Availability Predictor model was used to predict field N mineralization rates for the mulga woodland and 21-year-old buffel pasture by using a medium-term (6-week) laboratory incubation to establish basal rates of N mineralization. The Soil Nitrogen Availability Predictor overestimated annual net N mineralization in the 0-30 cm depth of mulga by 9% and underestimated it by 28% for the old buffel pasture. The Soil Nitrogen Availability Predictor could be modified further to accurately predict net N mineralization for the mulga woodlands.

Notes: Study covers the area from NW of Charleville in Qld to about Bourke in northwest NSW. Clearing of mulga woodlands for pasture development can substantially decrease soil N stocks leading to a potential decrease in soil fertility and plant productivity.


Notes: Results of a survey of the southern mallee region in the Western Division of NSW. Includes the vegetation and fauna of the sandplain mallee, dunefield mallee, Scotia mallee, remnant mallee, riverine woodlands, Belah woodlands, shrublands and grasslands.


Abstract: This note outlines preliminary research conducted in 2004 under white cypress stands in the western Pilliga State Forests. The aim was to describe soil conditions and floristic composition in managed or unmanaged stands to determine if dense regrowth had an effect on some aspects of environmental condition. The study found that species richness appeared to be unaffected by the density of White Cypress pine and that N was equally available regardless of management but opportunities for nutrient uptake are probably limited by rainfall. Study suggests that thinning of cypress pine in the Pilliga forests had minimal impact.
on plant species richness and diversity and soil condition. So management of regrowth is not detrimental to site quality. This study being expanded into a PhD.


Abstract:

Notes: Summary: Droughts are inevitable in Australia's rangelands. This report is motivated by the proposition that Australia's rangelands will be better managed for future climate variability by better understanding the mistakes and successes of the past. Evidence of land and pasture degradation is the loss of edible perennial grasses and shrubs resulting in soil erosion, soil structural decline and infestation of woody weeds. Heavy utilisation and drought in the 'normal' growing season results in the loss of desirable perennial plants.

Eight major degradation episodes have been described from across Australia's grazed rangelands. Review of degradation episodes and subsequent partial recovery confirmed that year to year variation in rainfall was a major driving factor in both degradation and recovery but simplistic to focus on rainfall as the major cause of degradation - drought has been a feature of the Australian landscape for maybe thousands of years. Too many animals were carried for too long on areas under stress from drought. The problem graziers have is that they can only really control domestic stock.

From this investigation there are several commonalities:
1. Overexpectation of safe carrying capacity
2. Total numbers of graziers and some woody weed regrowth increased in response to mainly above-average rainfall that preceded the drought/degradation episode.
3. These phases were early 1890s, 1916-18, early 1920s, mid 1950s, early 1970s and late 1990s coincided with a cool phase of the IPO/PDO.
4. Intermittent dry seasons/years resulted in heavy utilisation and degradation.
5. Extreme utilisation in the first years of drought by retaining stock caused further loss of perennial species exacerbating the effects of subsequent droughts.
6. Rapid decline in commodity prices led to stock retention.
7. Continued stock retention exacerbated damage to the resource and delayed recovery.
8. This led to rapid decline in surface cover and resource damage.
9. Drought sequences have occurred more often when the IPO/PDO indices were in the warm phase.


Abstract: In this paper a brief outline is presented of the major biological processes which operate in mulga lands, and consideration is given to how these processes can be manipulated to make the best use of these lands. Managerial actions which will maintain and
possibly increase animal production commensurate with an acceptable level of diversity and vigour of native flora and fauna are described. Critical points in the system where man’s intervention will have most effect are indicated. Key factors which maintain land in a productive condition and favour rehabilitation of degraded areas:
- use of fire during runs of good seasons in shrub infested areas
- reduction of grazing pressure during drought and post-drought periods
- control of TGP
- maintenance of 160 mulga trees/ha
- stocking of country in poor condition with a high proportion of cattle
- appropriate determination of living area requirements
- drought relief measures which take pasture condition into account and clearly differentiate between welfare and land management objectives.

Notes: The mulga degradation cycle - drought, &/or excessive grazing pressure increases proportion of bare ground and unpalatable pasture plants leading to increased runoff and loss of soil; resulting sheeting of the soil surface leads to greater runoff and soil loss; infiltration decreased so there is less plant growth, more runoff etc; concurrent increase in unpalatable shrubs. Sheet erosion most evident - removes 1-5cm of topsoil. Nutrient recycling by vegetation significant in these soils but loss of surface soil substantially affect soil fertility (lower organic carbon, total nitrogen, acid phosphorus, replaceable potassium and total sulphur in eroded soils). In the absence of fire mulga and/or other woody shrubs tend to become dominant in areas with >300mm rainfall - this scrub is stable but unproductive - 10% canopy cover of green turkey bush reduced pasture biomass by 2/3rds. TGP - other authors have indicated that the greatest danger is caused by a high grazing pressure during and immediately following droughts. Evidence indicates that complete recovery of the land does not fully recover with runs of good seasons if sensitive lands are subject to continuous high TGP for extended periods - carrying capacity appears to have dropped from historical levels. Very heavy grazing resulted in the rapid decline in the proportion of palatable species in only 6 years.

Rehabilitation: grazing management and fire - chemical control, waterponding, ripping, etc considered inappropriate.

Fire: Small cool fires preferable to bushfires. The relative speed with which perennial grasses set seed compared with woody shrub species enables pasture grasses and herbs to have a competitive advantage during this stage so small frequent burns provide a competitive advantage to grasses and herbs. Ground cover essential to reduce soil erosion but difficult during droughts except for leaf fall from trees and shrubs. In drier areas contribution of mulga litter to ground cover is massive so the maintenance of a moderate density of mulga trees - density equivalent to 160 shrubs/ha (8m spacing) - is important.

Abstract: The history of settlement of the semi-arid rangelands of western NSW is reviewed with respect to changes in the vegetation and soil which occurred under a regime of European land management. Simple dynamics of the vegetation response to grazing are illustrated and primary archival data is explored to verify the status of traditional wisdom about three examples of perceived change; the extent of the pioneers knowledge of land degradation, the timing and causes of the 19th century Callitris pine regrowth events, and the importance of soil compaction. In each case it is shown that the traditional wisdom surrounding these issues is partly erroneous and that folklore is in danger of becoming accepted fact. Such errors must be avoided if we are to improve range dynamics models and management.

Notes: Discusses background to settlement - cattle replaced by sheep mostly by 1860s. High stock levels during a period of above average rainfall led to changes in veg with grasses replacing shrubs. Evidence from historical sources indicates that by the 1870s the composition of native vegetation had shifted from saltbush in only 25 years of grazing and scald erosion was probably occurring. Suggests that in comparison with the rest of the world, native herbivores were probably only a minor feature of the ecosystem and when replaced by domestic stock it was an invasion of a system with little resistance to heavy grazing. The native veg mostly lacks adaptations like subterranean buds and protected vegetative parts except those species which have them as fire and drought adaptations - immediate degradation. Plants in the semi-arid zone have to cope with stresses induced by water shortage, extreme desiccation, low nutrients, moderate to high salinity and occasional fire - grazing regime imposed by 5 dominant herbivores (cattle, sheep, horses, rabbits and goats). Response to this additional stress:
Decreased abundance - Demise of old man saltbush has been attributed to vegetation change in the 1860s. When saltbushes eliminated annual grasses took over in the Riverina but in SA bare ground was more common.
Increased abundance: those not preferentially grazed or respond by tillering etc.
Exotic invasion: Mostly increasers.

Analysis of historian data leaves little doubt that travellers and settlers were well aware of damage being done to the rangelands well before the invasion by rabbits and the drought at the turn of the century.

What is the future of the arid and semi-arid rangeland in NSW? in 1980 some graziers said in parts of the west that there were only 20 years left in the industry unless some cheap means of controlling woody shrubs was developed. Prescribed fire for control become 'more common' but this is not always successful and may only be a short-term solution wherever fire tolerant shrubs form even a small proportion of the problem species.


Abstract: Observations made in the western division of NSW have confirmed that goats are useful in the management and utilisation of Australia's semi-arid rangelands. Experience in
similar areas of the world, such as Texas and South Africa, has shown that goats are a useful tool and are efficient users of semi arid rangelands.

**Notes:** Goats are selective feeders though they select from a wider range of plants than other livestock. They prefer more fibre than either sheep or cattle and use it more efficiently. Browse is not an essential component of goat diets but a relatively high fibre content seems to be important. Diet varies throughout the year and with plant stage.

Goats are very mobile with several changing camp sites. Control of TGP is critical and fencing is necessary. Some trials have suggested that goats can have an advantageous impact on woody weeds.

*Effects on range condition (observations by landholders):* goats reduced shrub problem and improved range country, they had little impact on mature turpentine or buddah but no seedlings observed; at very high stocking rates they rapidly kill hopbush and defoliate mulga but mulga mostly survives, at lower densities they reduce densities allowing more grass growth; they cause less damage to country surrounding watering points and camps and use pads less intensively then sheep or cattle - they graze all over the paddock; easier to manage than sheep.


**Abstract:** Contents: Geography and Climate; Vegetation (short grass-forb pasture; perennial wandarrie grass pastures; saltbush-bluebush pastures); The Pastoral Industry; Interaction of Pastures and Livestock; Problems of the Pastoral Industry; Pasture Management; Administration; Other Land Uses; Conclusions


**Abstract:** The mammals of inland Australia were seriously affected by European settlement and a high proportion declined dramatically in range or became extinct. Native birds fared much better and no species are certainly extinct. Reptiles have suffered no extinctions and no apparent reductions in range. Among the mammals there are clear biases in the species which suffered most; medium-sized species, most of them herbivorous or omnivorous were devastated. A conceptual model to account for these patterns is developed. It proposes that the environment of inland Australia was originally difficult for herbivorous and omnivorous mammals to inhabit because of the infertility of the soils, and the consequent restriction of digestible production to small fertile areas. This problem was exacerbated by the uncertain climate with its droughts of irregular length. The consequent restriction of these
types of mammals to scattered pockets of suitable habitat during droughts exposed them to high probabilities of local disappearance.
The arrival of grazing stock and the rabbit upset the balance between local disappearance and reinvasion after drought. The introduced herbivores maintained extraordinarily high populations for a short time and, in doing so, altered the vegetational composition of the very habitats upon which the native species had been dependent for refuge during droughts. This degradation, together with the pressure of introduced predators and, in some places, altered patterns of fire, caused increased probabilities of local disappearance. Several droughts later, extinctions resulted.
A variety of apparently conflicting evidence is weighed up and resolved. Conclusion that the model not only has potential explanatory validity but also has substantial management implications.

Notes: Nutrient distribution in the landscape and a patchy environment are key to this theory. Key to this is maintenance of a patchy environment using tools such as fire.


Abstract: Attitudes to conservation in the rangelands are shifting rapidly as cultural change alters the ways in which Australians view their history and environment. In earlier times, pastoralists of the outback were seen as admirable pioneers; today, not all Australians hold such a view. In an effort to predict how trends in social change might affect conservation issues I review recent events in the forest and fishing industries, which like the rangeland industries are to some extent based upon public land or resources. The forest industries have been under sustained attack from conservationists, whereas pressure on the fishing industry has emanated from scientists and governments worried about sustainability. Both industries are changing in response to these pressures, and it is possible that animal production in the rangelands will eventually experience similar forces. I suggest that in the long run the rangeland industries will be unable to ignore change, and that in fact the social currents may provide new opportunities.

Notes: Rangelands lie between forests and fisheries re social & cultural currents of resource use & conservation. Increasing public interest and government interest in the economics of managing natural resources.

Abstract: Fire-driven succession creates opportunities for a more diverse regional fauna but the spatial patterns of burning are not important for the persistence of birds and reptiles in spinifex grasslands.

These results may not apply outside the alliance in which the work was conducted. Feathertop spinifex *Plectrachne schinzii* burns relatively frequently and the situation may be somewhat different in other associations. These results are also difficult to extrapolate to other biomes.

Notes: This study in the Tanami Desert was designed to determine the influence of the patch burning strategy on vertebrate diversity and abundance in spinifex grasslands tested the hypotheses that:
- diversity and abundance of most faunal taxonomic assemblages change predictably as the vegetation succession changes from the immediate post-burning state to maturity;
- species richness or abundance of a particular taxonomic assemblage is greatest near the edge of a patch and decreases with distance from that edge; and
- within a particular successional state, the species richness of a particular taxonomic assemblage increases with patch size.

The response by bird and reptile species to these scenarios varied between species groups and particular species, with the strongest species response correlation being with time since fire. The results for edge effect and patch size were more equivocal. There was no simple relationship. The problem of spatial scale is again evident as this study sampled only a tiny portion of the vast Tanami Desert. The use of plant communities of varying ages provided a surrogate for temporal variation but the data were collected during a particular set of climatic conditions.


Abstract: Arid and semi-arid lands cover 70% of Australia and bear a legacy of degradation and species loss from past policies and management. Pastoralism, the most extensive industry, as well as other land users and the community at large, are seeking sustainable use of these lands in the future. This paper outlines a new approach to the problem of integrating conservation and production.

We clarify the distinction between the individual manager's enterprise goal of sustainable land use, and the community's goal of regional conservation of biodiversity through ecologically sustainable land management. From an understanding of the functioning of productive (relatively fertile and moist) and unproductive (infertile and arid) parts of the landscape, we then develop a conceptual framework for landuse within areas that have
priority for conservation management. We describe a system of management which integrates national parks with off-reserve protection. Landscape elements for management are defined to include national parks, excised management units, restricted use units and a sustainably managed majority. The financial resources that society would need to dedicate to the stewardship of the land are made transparent by a methodology for assessing the relative importance of different areas. In areas which are marginally productive for livestock, we suggest that unambiguous financial assistance could enable managers to remain on the land; they would assist with the management of feral animals, weeds, fire and local reserves, in exchange for the certainty that any residual use of the land was sustainable. We put priorities on outstanding research issues. These arrangements would enhance the process by which all users of arid Australia - whether pastoralists, tourist operators, Aboriginal people of park managers - come to act as land stewards, obtaining services from the land in an ecologically sustainable manner. We discuss the cultural and political changes that are needed to permit this scheme to evolve from its present conceptual state to an operational system, emphasizing the fact that the informed involvement of current land managers will be crucial.

**Notes:** Pastoralism occupies 66% of the Arid Zone. Includes map of primary landuses of the arid zone - sheep (NSW, inland Qld, southern SA, western WA), cattle, Aboriginal Land (15%), conservation land (4%) - 22% meat & 14% wool production of Australia. Tourism & mining increasing in importance. The loss of biological diversity has been caused by the same functional changes that have caused a decline in pastoral productivity.

Whatever the future uses of the arid zone the problems of feral animals, weeds, soil erosion and fire will still exist. More than half Australia’s endangered mammals, a third of the threatened birds and a tenth of threatened plant species are for the arid and semi-arid lands. Ecosystem function: 3 basic landscape types - one with relatively rich soils (Mitchell Grasslands, Chenopod shrublands), second, more common type, dominated by poor soils (spinifex grasslands). In the 3rd type patches of productive country resulting from the concentration and redistribution of water & nutrients are scattered through the resource poor landscape. Introduced herbivores preferentially select resource rich areas. In contrast with America and Africa the Australian rangelands have not experienced heavy grazing by ungulates (as have these other parts of the world) for at least 30,000 years as a result of unreliable water and Pleistocene megafaunal extinctions. The arrival of introduced grazing animals and the provision of artificial waters have had a dramatic effect on the native biodiversity that live in the resource rich areas. Species sensitive to grazing have declined. The impact has been exacerbated by introduced predators and weeds as well as incidental changes to fire regimes. Conservation problems in arid Australia are not the product of loss of habitat through clearing and fragmentation. Ecologically sustainable management relies on maintaining the ecological function of resource rich areas. The process of allocating land to the various management units is discussed in detail.

Abstract: Includes: Geography; Ecological Characteristics (northern tallgrass woodlands; eastern tallgrass woodlands; midgrass woodlands); the Pastoral Industry; Improving Pasture and Animal Productivity (burning; tree removal; feed supplements and pasture improvements); Stability/resilience Factors; Non-Pastoral Uses (cropping; aboriginal uses; forestry; reserves; mining); Conclusion


Notes: The combined effects of European man, livestock, rabbit and the efficiency of today's firefighting techniques a previously frequent occurrence to a once in a lifetime event in some vegetation types; it is possible that there will never again be sufficient ground fuel to support a fire of any magnitude due to heavy long term grazing, loss of surface soil, dramatic increase in unpalatable shrubs.


Abstract: Following a sequence of favourable years in which pasture growth over much of the arid zone of Australia reached very high levels, controlled burns were carried out on two contrasting vegetation types in the extreme north-west of New South Wales. A wheel-point apparatus was used to measure subsequent changes in botanical composition and foliage cover over a four year period. On a pasture periodically dominated by Mitchell grass (Astrebla spp.) burning while growing conditions were favourable resulted in only a small long-term decrease in the cover of Mitchell grass. In the short-term all chenopod species were eliminated and a wider range and greater abundance of annual forbs were promoted in the following spring. On a similar area burned by wildfire in a year of low summer rainfall the response from Mitchell grass was much poorer and botanical composition of the pasture present in the following spring differed from that which developed in the spring following the controlled burn. It also differed from that of the unburnt pasture. The major differences were due to the response of forb species and are attributed to variation in seasonal rainfall. On a dune-system pasture the dominant grasses were species of Aristida and Enneapogon. These are relatively short-lived and appear to have little ability to regrow from the butt after fire. Their slow regeneration after the burn was reflected in the substantial increase in relative abundance of perennial forbs in the following autumn, and of annual forbs the next spring. Although fire appeared to have no long-term effect on the pasture it dramatically reduced tree and shrub numbers. It is suggested that during years in which abnormal quantities of Mitchell grass are present in this region, controlled burning could be a useful form of management. A mosaic of patches burnt at different times would reduce the potential for
wide-scale wildfires, provide refuge areas for stock and wildlife in the event of wildfire, and promote a wider choice of plant material for grazing animals. However, in dune-systems vegetation, removal of the pasture cover and reduction of the tree and shrub density would constitute an erosion risk.

Notes: Assessed the impact of both control burn (1976) and wildfire (1980) on vegetation in Sturt National Park after massive rains of the 1974-5 period produced huge pasture growth. Burns by NPWS undertaken to assess value of control burns to restrict wildfire and protect habitat. Chenopods eliminated initially but no difference 3 years later, annual forb response with rain, poor recovery of Mitchell grass, burning when soil moisture conditions are still favourable for plant growth has little impact but advantageous when soil moisture is low.


Notes: An important reference which summarises issues relating to fire in the rangelands of Australia. Document includes:
1. Why is fire management important in the rangelands
2. Fire management planning checklist
3. Fire ecology of the rangeland ecosystems
4. Principles for information dissemination, technical transfer and capacity building
5. Criteria for setting priorities for development of fire management plans
6. Information requirements and critical knowledge gaps


Abstract: Rangelands are relatively undisturbed but the abundance & richness of rangeland biodiversity is declining and inappropriate fire regimes are considered partly responsible. No single fire regime applied at a landscape scale can meet the needs of any one major land management objective let alone multiple land management objectives. Appropriate fire management practices will vary with factors such as the desired management outcomes, climate, terrain, flora, fauna, and the scale and patchiness of the ecosystem. While some elements of rangelands ecosystems are resilient to changes in fire regimes, others are sensitive to fire intensity and/or fire interval. This paper aims to help managers develop appropriate fire management practices.

Notes: Although fire is an important management tool there are many gaps in our knowledge of how it can & should be used. If used poorly fire can degrade ecosystems and reduce
productivity, contribute to soil erosion, expand weed and feral animal populations, reduce water quality, increase soil salinity, cause declines in native plant communities & decrease biodiversity. It is essential to build capacity, community engagement and co-operation (3 Cs) to ensure fire is used as an effective tool in achieving sustainable rangelands.

**Australia has 3 major fire/climate regions:** Wet-dry tropical savannas - landscape-scale fires are annual, fuels accumulate in the wet season, mostly occur in dry season May-Dec when fuels have cured; Semi-arid & arid interior - landscape scale fires are episodic, at intervals of up to a decade, only after periods of exceptional growth when fuels have increased due to above average rainfall - fires mostly spring-summer, Sept to Jan; Southern temperate zone - episodic landscape-scale fires, when there is both drought and severe fire weather.

Use of fire as a tool needs to be understood within a local or regional context - different goals e.g. improving pastoral productivity, increasing biodiversity, protecting habitat or property from wildfire may require different fire regimes.

**General principles re fire & biodiversity:** ecological effects determined by fire regimes; flora & fauna species have limits of tolerance to fire regimes which can be exceeded; ecological effects can be predicted if thresholds are known, monitoring necessary to verify ecological outcomes; variation in plant communities determined habitat quality; fire regimes are shaped by past events; land managers need to understand the effects of fire regimes at broad spatial scales - especially potential losses of species that may occur at a landscape scale; adverse fire regimes may fragment landscapes.

**Engaging communities in fire management:** indigenous communities, fire management plan, setting priorities for development of fire management plans, information requirements and critical knowledge gaps.

**Implementation issues:** It is well recognised that a fire created mosaic - varying both in space & time - meets the variable needs of flora & fauna better and maintains a higher biodiversity than in more homogeneous fire landscapes - monitoring and adaptation are essential.

**8 Broad vegetation types of Australian rangelands:** they each show a range of responses to fires & its impacts - no single landscape regime can meet the needs of management objectives; within each major veg type patches of other vegetation often occur and require different fire management from the surrounding vegetation. Veg types:

- **Tropical eucalypt savannas:** Fire has important role & most Australian fires differ in this veg type - fire driven by the monsoonal climate. Fire intensity affects tree density, frequency affects health, seedling production, growth etc. Patchiness extremely important to animal populations and communities. Fire management issues in savanna rangelands include: thickening of woody vegetation due to deliberate fire exclusion and the reduction of fuel loads from grazing; implementing mosaic landscape fire and monitoring its effectiveness; the role of changing fire regimes in the decline of animal populations; fire abatement; reducing the area annually burnt; role of fire management in abating greenhouse gas.

- **Melaleuca woodlands in rangelands of monsoonal northern Australia:** current fire practices are not meeting management objectives for conservation or production purposes. In high rainfall areas where most melaleuca forests & woodlands occur 50-70% of the landscape may be burnt annually. Fires are often suppressed and grazing in pastoral areas, reducing frequency & extent. Woody thickening is occurring - led to the decline of granivorous birds e.g. golden-shouldered parrot, star finch, Gouldian finch, buff-breasted button quail, black-faced woodswallow. Optimal fire regime to ensure year round food availability is one that
controls woody thickening and retained a fine-grained mosaic of areas burnt at different times of the year.

**Tussock Grasslands:** Mostly in Qld - Mitchell, bluegrass grasslands. Fire can be used to manage pasture composition but effects are generally unknown on biodiversity. Fire ecology & management differs between tropical and temperate grasslands. Fires are now less frequent and less patchy than those lit by indigenous Australians prior to European settlement. Mostly annual burns in tropics; long and irregular intervals in temperate grasslands. Fire can promote vigour in Mitchell grass. Patchy fires are important in arid & semi-arid tussock grasslands to maintain habitat for endangered species e.g. western hare-wallaby, bilby, mulgara. Many knowledge gaps.

**Hummock Grasslands:** Fire important as management tool and because wildfires impact on infrastructure, productivity & biodiversity. The most extensive wildfires usually occur after periods of widespread above-average rainfall leading to increased fuel. Since European settlement general shift from numerous small fires to less frequent large intense fires which homogenises the spinifex stands. Generally have a negative impact on biodiversity including fire sensitive vegetation communities. Extensive fires in central Australia (2000-2002) demonstrated that more effective fire management required regional plans and a commitment to participation across land tenures and managers. Mapping resources are essential.

**Temperate eucalypt & open woodlands:** SE & SW Australia. Fire is largely driven by fuel accumulation after rain - incidence generally low and declined due to fragmentation of landscape and total grazing pressures. Overgrazing has led to the replacement of perennial grasses with ephemeral grasses and herbs or dense shrub layer and change in fire regime. Fire can promote seedling regeneration in woodlands by opening up spaces but its role in regeneration is unclear - resprouters (Eucalypts, Kurrajong), obligate seeders (Callitris, Mulga) and shrubs can be either of these. Fire regimes largely driven by rainfall & caused by lightning (eg 1974-5, 1884-5). Fire regime varies with the amount of litter fuel and its continuity over the landscape and variable amounts of herbage present in a response to rainfall and grazing. Significant knowledge gaps on impact of fire on biodiversity conservation in this area.

**Acacia forest, woodlands, open woodlands & shrublands:** In mid-latitudes of arid & semi-arid rangelands. fires more frequent resulting in change to grassland and loss of diversity. Mulga, brigalow, lancewood, bendee, myall, gidgee. Mulga covers 20% of Australia. Fires depend on build up of grassy or herbaceous fuels which depend on rainfall since last fire - and TGP. Frequency therefore varies from 2-3 years in the north to much less frequent further south. Significant knowledge gaps.

**Chenopod shrubs, samphire, forblands:** semi-arid & arid zones with reliable winter rainfall. Fire should be excluded from these shrublands because the dominant species are unable to regenerate after burning. Extensive areas degraded by pastoral management, grazing. Lack of seed storage means that a single fire can deplete or eliminate the plant population but relatively fire retardant due to high salt content in foliage. Careful management to prevent the dominant shrub layer from degrading is a continuing priority - degradation of chenopod shrublands may increase the potential for large landscape-scale fires.

**Mallee:** Mallee communities, except for those with chenopod understorey are flammable and may burn regularly. These communities show remarkable resilience after fire with most perennial species resprout vigorously after fire but the resprouting capacity of mallees to
under annual or biennial burning, particularly in autumn. Faunal diversity requires a range of post fire ages to survive. Typical fire cycle 10-20 years reflecting fuel accumulation and above average rainfall - major fire seasons 1957, 1975, 1985 & 2002. In highly fragmented mallee landscapes remnant vegetation may experience little or no fire. In NSW quantitative evidence suggests the optimal fire interval range of 10-40 years is appropriate.


Notes: More than 75% of Australia is defined as rangelands including tropical savannas, woodlands, shrublands and grasslands.
The Audit is working with the ACRIS Management Committee to compile a national report in 2007 on change in the rangelands. Indicators of rangelands change will be expressed under a number of broad themes: landscape or ecosystem change, sustainable management, biodiversity change, sustainable water management, social and economic change, and climate variability.

Contains link to the report 'Reporting Change in the Rangelands'.


Notes: Key messages: different vegetation types are adapted to different fire regimes; too frequent AND too infrequent fires can trigger negative impacts and throw systems out of balance e.g. loss of species, weeds; even within a single vegetation type different species have different needs in relation to fire so need to very fire frequency over time & space to allow for the full range of species; each post fire successional stage is different; burn in patches, provide wildlife refuges and a seed source for plant and animal recolonisation of burnt areas; remember the landscape context; co-ordinate fire activities with neighbours to develop a mosaic; in planning remember unplanned as well as planned fires.
Discusses plant responses to fires - obligate seeding and resprouting.
Fire regimes: Include frequency, extent, intensity, season. Repeated fire intervals are not necessarily advantageous to biodiversity. Intensity depends on wind speed, temp, humidity, slope, fuel load and vegetation structure; variation in intensity important for maintaining biodiversity.
Consider biodiversity as assets (as acknowledged in the Rural Fire Act 1997) and plan for them.
When making decisions re frequency planner needs to be clear about land management objectives as tis should vary across the property. Prepare a property fire management plan.


Abstract: Is there a balance between wildlife conservation in western New South Wales and any other land management there? The answer is a resounding NO! The ecological functioning of the region is dominated by introduced systems of herbivory and predation: sheep; rabbits; feral goats; their partial heritage the increased abundance of kangaroos; and their predator-prey complex of foxes, feral cats and rabbits. Conservation can only have what is left over. Even on National Parks where there is no sheep grazing, the rest of the unbalancing complement of herbivores and predators is in place.

The removal of dingoes has been part of the destabilising process. Where dingoes remain on the South Australian side of the Border Fence, there are few red kangaroos, no feral goats, and foxes are not so prevalent as in adjacent NSW. It would be no solution to release dingoes back into NSW because those species are now so abundant.

How can balance be regained in western NSW? Pest species will have to be controlled; but it is not simply a matter of removing the offending animals and re-introducing the vanished (if extant). Firstly key habitats for species must be identified and the vital ecological resources restored within them. Historical information may help in doing so. Because ecosystems have been so changed, the programme of restoration may have to begin from the ground up, i.e. with soils and vegetation.

Notes: Discusses the changes in mammals in western NSW - increasers (red kangaroos & introduced grazers) & decreasers (native medium sized species). 15 million sheep in 1890s which then crashed and returned to the much reduced 5 million until myxo removed most of the rabbits. The lost rabbit biomass was probably converted to 1.5 million more sheep and probably kangaroo biomass. In central & western NSW Burrowing Bettongs were extinct by the 1890s, before the advent of the fox - as for other native mammals according to Aboriginal memory.

Ecological interactions: There is a profound imbalance between populations of native and introduced mammals in western NSW. Two major ecological processes predominate, involving mostly introduced species - herbivory (sheep, rabbit, goats, 3 species kangaroos - the increasers) and predation (the system dominated by the fox, feral cat/rabbit dynamic). Pest control is one method but this is difficult on the large scale of western NSW. Ecological reconstruction of habitats is also required. Fencing is probably the best method.


Abstract: The aim of this chapter is to try to assess the place of fire in the life of the Australian Aborigines.

Notes: Provides a synthesis of historical and recent observations and assessments regarding the use of fire by Aboriginal people - pre-European settlement. The greatest majority of more detailed information comes from central, northern and western Australia with some earlier observations relating to the east coast. Apart from explorers diary comments about observing fires there appears to be very little information on how fire was used in western NSW. Regarding early observations - how much smoke was from controlled cooking fires and how much from bushfires or lightning strikes is questionable.

Discusses the various uses of fire by Aborigines: used most extensively by men, paths maintained by fire in more dense bush - deliberately and accidentally; For hunting fire reduced effort and in the wake of a fire women and children collected insects, reptiles, birds, mammals killed or exposed by the fire. In the spinifex grasslands of central Australia Finlayson provided an account of highly skilled management of fire to capture mala. In the western desert there are accounts of extensive fires that were allowed to burn out of control. Post fire rain would increase food availability. Similarly in the tropical rangelands fires appear to have been used skillfully and throughout the dry season.

'The factor of fire has been little understood and has been subject to much exaggeration as well as lack of discrimination. Generalisation is always dangerous and nowhere more so than in the matter of vegetation.

The central issue is: Did grasslands develop as a result of Aboriginal fire or were they formed during earlier, possibly arid climatic conditions and were simply maintained by fire? [probably both] This question is equally applicable to North American grasslands where the opinions of ecologists are not unanimous. In America as in Australia there is nothing recorded scientifically; there is no basic data from the contact period when European man and his domestic herbivores arrived. They destroyed the evidence! Conclusions about the effects of fire are personal opinions only.


Abstract: Data from the Koonamore vegetation reserve are used to illustrate several points which must be kept in mind in developing models of the dynamics of arid ecosystems. These include the importance of the abiotic environment in determining the dynamics of the biotic, the phenomenon of 'inertia' and the role of the fortuitous co-occurrence of several low probability events in triggering changes in arid ecosystems.

"Land belongs to a vast family of which many are dead, few are living, and countless numbers are still unborn." (CK Meek quoting an unnamed American Indian)

If we are to manage our rangelands in a way which does justice to the efforts of those now
dead, which provides an adequate living for we few now alive, while still protecting the rights of those unborn, we need a sound understanding of the dynamics of range ecosystems.

**Notes:** Dominance of the biotic by the abiotic: Strong link between lagged rainfall and leaf biomass - rainfall is dominant.  
Inertia: Wide variations in turnover response and turnover times emphasize the importance of considering the details of the population biology of the species in range dynamics.  
Co-occurrence of low probability events: Rangelands dynamics are dominated by the fortuitous co-occurrence of a sequence of events where each event has a low probability of occurring.


**Notes:** Contents:  
Ch 1 Introduction (The great central scrub - an early warning; Drought & devastation)  
Ch 2 The 1900 NSW Royal Commission - a critical re-evaluation (The Commission's findings; Rabbits ringbarking shrubs)  
Ch 3 Pastoral Science in Western NSW - an Historical Overview (Pastoralism & the farming frontier)  
Ch 4 Research into Shrub Ecology and Management (Defining ecological processes (1965-74) - grazing and fire interactions, chemical treatments; Alternative control options (1975-94) - Biocontrol by grazing, Control through prescribed fire, mallee eucalypts - archetypal fire sprouters, budda & turpentine - alternative sprouter syndromes; Integrated shrub management systems)  
Ch 5 Integrating Mechanical, Fire and Chemical Treatments - Some Case Studies (Herbage response to shrubband/or tree thinning; Vegetation mosaics or multiple stable states?; Case studies of multiple treatment strategies - Fire + fire systems (hopbush in mulga woodland on sandy red earth), fire + fire or chemical systems (punty bush in ironwood/mulga woodland on sandy red earth), Mechanical + fire + chemical systems (firebush in gidgee/mulga woodland on red earth)  
Ch 6 Conclusions (Changing perceptions; future research)  
Ch 7 Epilogue - an abridged Lawson anthology  
Ch 8 References & Bibliography  
Ch 9 Appendices

Notes: Describes the early stages of the mallee prescribed burning experiments on Birdwood Station.


Notes: In western NSW most of the common mallee species can occur as 1-3 stemmed trees known as bull mallee to 10 high or as multistemmed whipstick mallee 1-3m high. Highly inflammable Triodia frequently grows in association with whipstick mallee on the dunes and fire is common; bull mallee grows in the more open swales where fire is very infrequent, only occurring when ephemeral fuel, particularly spear grass is available. In higher rainfall regions mallee & mallee heath burn regularly. Fire is less frequent in the lower rainfall mallee communities fringing the arid rangelands. In experimental burns, few trees die when burns were in spring but significant deaths occurred after 2 successive autumn burns.


Abstract: This chapter describes some of the principle features characterising the management of mallee lands used primarily for pastoralism in semi-arid Australia. Characteristics (distribution; landforms, soils and climate); Vegetation; Fire in Mallee (Fire ecology; prescribed fire; operational requirements; wildfires); Pastoral Land use in Semi-Arid Mallee (industry characteristics; management problems); Land Administration; Cropping Marginal Mallee Lands; Conservation; Conclusion.


Abstract: Details are presented of prescribed fires imposed over several mallee areas ranging from 120 to 10,660 hectares. Particular attention is directed towards seven of these burns designed to assess the potential usefulness of aerial ignition for prescribed burning of large mallee paddocks. This ignition procedure is highly discriminating, enabling areas carrying sufficient fuel to be safely, and rapidly, burnt by numerous small fires resulting from aerial incendiaries released on a predetermined grid pattern. Fuel in the largest paddock burnt was ignited in two hours after releasing 13,000 spherical (3 cm diameter) incendiaries. In addition to overcoming problems of discontinuous fuel restricting spread of fire when using ground ignition procedures, this aerial technique also enables fuel to be ignited over large areas during narrow 'time windows' when optimal temperature and humidity conditions
apply. On one mallee property, a prescribed fire programme based on autumn burning by aerial ignition in 1980, 1982 and 1985 resulted in substantial improvements in sheep productivity and husbandry. Lamb weaning increased by 30% and overall stocking rate was doubled, resulting in a gross margin increase from $2.31 to $5.88 per hectare. Such economic benefits following a reduction in mallee density will only accrue in open mallee communities where speargrass is the major herb and a multiple fire regime can be imposed. In mallee dunefields, where porcupine grass is the dominant understorey species, infrequent (every 15-20 years) single fires are the norm due to the time required for this perennial grass to regenerate. More frequent burning is generally precluded because the light textured soils of the dunes cannot produce sufficient ephemeral herbage, especially speargrass, to carry a fire.

**Notes:** The Brompton Fire Rat (Wedd 1978) useful for burning out small areas of open mallee. Aerial ignition works better and can be effectively used in the prescribed burning od Aust rangelands. Fire season is based on whether or not a fire will run and is the dominant feature of prescribed regime and it also has an important influence on plant populations


**Notes:** Wildfire frequency: difficult to estimate but the fact that Edward Eyre and Ernest Giles travelled through dense mallee scrub which bordered on the impenetrable suggests that much of the mallee was burnt only infrequently. The degree of patchiness in mallee induced by Aboriginal fires is still a matter of conjecture. Pre-fire cover dominated by Triodia and mallee eucalypts switches to herb cover following fire. Soil hummocks developed by soil accretion around triodia hummocks are exposed by fire and are rarely colonised by herbs because of the water shedding properties of the soil. Herbs grow within the inter-hummock spaces and triodia and mallee return to the hummock sites. Mallee seedling recruitment (as distinct from coppicing) which introduces genetic variation did not occur after winter fires. Different fire regimes can have a significant influence on the botanical composition of mallee communities. Season of fire has by far the greatest influence and at community level this seasonal influence can be paramount in determining the botanical composition of post-fire herbaceous communities. The rarity of certain plant species may not mean they are endangered but may merely indicate the episodic nature of wildfire in semi-arid mallee. Fire x rainfall x grazing can pose important management considerations.

**Noble J. C. (1989) Fire studies in mallee (Eucalyptus spp,) communities of western New South Wales: The effects of fires applied in different seasons on herbage productivity and their implications for management Austral Ecology 14, 169-87.**

**Abstract:** The post-fire development of herbaceous understoreys of Triodia/mallee burnt in different seasons was studied over a 3 year period in south-western New South Wales,
Australia. Near Pooncarie, NSW, a 3 year sequence of above-average rainfall immediately following burning in either the spring, autumn or winter resulted in a substantial increase in species richness and herbage dry matter production. Plots burnt in the spring produced significantly more dry matter than either the autumn or the winter-burnt plots but only in the first growing season after burning. Some species such as *Haloragis odontocarpa* behaved as ephemerals, being abundant in the first post-fire season, particularly after spring fire, before becoming inconspicuous. Short-lived grasses, such as *Stipa* species, then became relatively abundant except during drought. Other experiments confirmed the potential of fire to increase herbage diversity and productivity when there was adequate rainfall. During drought, post-fire herbage production was low and the dominant perennials, viz. mallee *Eucalyptus* and *Triodia irritans*, regenerated at the expense of the herbs. There was a strong negative correlation between combined mallee and *Triodia* cover and total herbage cover over time. Seedling recruitment of *Triodia irritans* was significantly higher on plots burnt in the spring at Pooncarie.


**Abstract:** Discusses: Characteristics of Degraded Rangeland; Vegetation Rehabilitation (rehabilitation through lenient grazing; prescribed fire; reseeding with native species; reseeding with exotic species); Soil Reclamation and Erosion Control (furrowing; pitting; waterponding; waterspreading; marginal farming); Conclusions.


**Abstract:** Conclusion: Studies undertaken over the past decade in *Acacia aneura* communities in semi-arid eastern Australia suggest that many landscape processes have been significantly influenced by a diverse complex of soil biota. The fossorial vertebrates, a major component of these biota, have been seriously depleted since European pastoral settlement. As 'landscape engineers' they were responsible for creating and maintaining a high degree of surface heterogeneity that promoted a diverse and productive herbaceous understorey. It has been postulated that their regional extinction has been a neglected facet of desertification that has yet to register its full impact on other key elements of soil biodiversity while relict 'engineered' features remain preserved.

**Notes:** In semi-natural rangeland ecosystems it is postulated that a much wider range of soil-inhabiting organisms, including fossorial vertebrates, is likely to have been involved in the maintenance of soil fertility. Landscape dysfunction follows a reduction in the size, density
and variety of small-scale patches leading to a reduction in the diversity of microorganisms dependant on patch heterogeneity.


Abstract: After briefly describing the nature of the dominant pastoral industries in the temperate semi-arid and tropical grazing lands of Australia, this chapter focuses on changes in fire regimes following upon European settlement and the impacts these changes have had on resident biota. In this context, the interactions between fire, rainfall, grazing and browsing are seen as pivotal in mediating fundamental ecological processes, and subsequent habitat process, in pastoral landscapes. While considerable effort has been expended on elucidating the impacts of different fire regimes on individual species in these ecosystems, very little research at a faunal community level has been undertaken since the topic was last reviewed two decades ago. Few management options are available to pastoralists other than those directed towards regulating the consumption of vegetation by either grazing or fire. Prescribed fire is now recognised as one of the few cost-effective tools available for maintaining biological diversity at an appropriate management i.e. paddock scale. None the less, considerable challenges still remain in developing reliable procedures for defining optimal fire/vegetation mosaics required to maintain or increase diversity of resident biota. Finally, after briefly discussing the functional significance of biodiversity in pastoral ecosystems, the chapter concludes by discussing theoretical considerations relating to ecosystem resilience and multiple stable states, and the roles of contrasting rainfall, fire and grazing regimes in mediating transitions from one state to another.

Notes: Begins with a description of the early days of pastoralism and degradation. Climate, soil, herbivores and fires are recognised as the four major determinants of vegetation structure in pastoral lands. Managing fire regimes in pastoral landscapes: A single prescribed fire is unlikely to achieve lasting benefits, especially when the management objective is to reduce the density of woody species. Integrated shrub control strategies involving combinations of control options e.g. chaining followed by fire, management of TGP, or chemical defoliation of 1-2 year old shrub seedlings. Spatial variation in herbage (fuel) is strongly affected by redistribution of rainfall from source areas into lower sinks or fertile patches which intercept overland flow.. This process not only redistributes rainfall but also surface soil and litter - high production 'islands' become scattered throughout a 'sea' of low production. Altered fire regimes and their impacts on vegetation in pastoral lands: Records to the 1901 Royal Commission indicated that " After the country became stocked, bush fires were less frequent. Previous to that every summer large bushfires swept through all that country and that tended to keep the down the scrub and undergrowth." This is improbable given that fires were dependant on the presence of perennial grass fuels which were present after favourable rains.
Grazing removed the fuel. While noxious scrub was blamed for much of the decline in productivity there was a reluctance to accept the notion that the changed vegetation was a symptom rather than a cause of the problem. Noble believes that there is 'strong evidence' that scrub proliferation is closely correlated with a reduction in fire frequency. In tropical rangelands changes in vegetation structure vary considerably. Some pasture systems are regarded as being under threat from woody regrowth but changed fire regime likely to be only responsible for 3 of these. In the Kimberley's the very high incidence of extensive fire is threatening pastoral and environmental values.

**Interactions between fire regime, rainfall, grazing and browsing:** Interactions between these factors are far more important than the effects of fire alone. In the tropical rangelands invasion by exotic shrubs (Mesquite, Prickly Acacia, rubbervine and Chinee Apple) is a major problem. In the semi-arid rangelands the amount and timing of rainfall are critical in determining the availability of short lived fuel species but the rainfall regime following fire dictates the composition and abundance of succeeding herbage communities, thus affecting grazing pressure and the subsequent vegetation structure. Discusses impact of fire on seeds and plant survival, as well as faunal communities based on several autecological studies.

**Biodiversity, landscape function and fire regime:** Because of the unpredictability of rainfall there is rarely any ordered succession of plant communities following fire disturbance in pastoral landscapes. Compositional changes across many different veg communities generally conform to: 1. early occupation and dominance by short-lived forbs and grasses depending on post-fire rainfall; 2. re-establishment of perennial species through basal regeneration and/or seedling recruitment; 3. progressive dominance by perennial species both woody and herbaceous; 4. slowing down of rate of compositional and structural change once perennials have matured.

Suggests that the significance of interactions between grazing, fire and browsing in regulating vegetation dynamics in semi-arid ecosystems may have been understated (role of Bettongs). Termites also important


**Abstract:** Previous fire experiments using artificial fuel have shown that annual fires, especially those applied in the autumn, can effectively control coppicing understorey shrubs in semi-arid woodlands. Such frequent fire is impossible to apply under natural conditions given the limited time available for sufficient herbage fuel to accumulate. Preliminary screening studies were therefore undertaken to test the hypothesis that chemical sprays applied at concentrations less than those normally recommended could be used to mimic high-frequency experimental fires. The effectiveness of 11 chemicals (7 arboricides and 4 desiccants) applied at a range of concentrations was assessed on one site by spot-spraying 5-year-old coppice regeneration of *Eremophila mitchellii* (budda or false sandalwood) and *E. sturtii* (turpentine). Chemical activity was assessed by regularly monitoring leaf effect, i.e. by rating the degree of leaf discolouration, scorching, blackening and ultimately leaf fall, over the
ensuing 12 months following treatment. Arsenal® and Roundup CT® induced the highest shrub mortalities across all size classes while mortality rates were consistently higher for *E. mitchellii* than for *E. sturtii*. A second experiment involved 5 chemicals (4 arboricides and 1 desiccant) applied in a similar manner to 7-year-old seedlings of *Cassia nemophila* (syn. *Senna nemophila*) (punty bush). Significant damage to foliage (> 80% leaf effect) of all 3 shrub species was recorded 2 months after treatment with either Roundup CT® or Roundup® (i.e. either 450 or 360 g/L glyphosate respectively), as well as with Arsenal® (250 g/L imazapur + 60 g/L isopropylamine) but only at the highest concentration (i.e. 100% of the 'recommended' rate). In some lower concentration treatments, leaf effect was still increasing 6 months after treatment.

In a second series of screening experiments involving 1- and 2-year-old coppices sprayed in autumn and spring, significant interaction occurred between coppice age and season of spraying when averaged over both Eremophila species. At lower concentrations (i.e. 12.5 and 25% of maximum recommended rate), autumn application of Roundup CT® was more effective than spring application, especially once regeneration was 2 years old. Gramoxone® was also most effective at all rates above 12.5% of the maximum when applied in the autumn to two-year-old coppice. However, Garlon® (600 g/L triclopyr) and Tordon 50-DA(r) (50 g/L picloram + 200 g/L 2,4-D) were more effective when applied to 1-year-old coppice in the spring. Overall, the most effective low-concentration treatment was Roundup CT® applied in the autumn to two-year-old coppice. Low-concentration treatment of one-year-old coppice with Roundup CT® and Arsenal® was also consistently more effective when carried out in the autumn (80–90% leaf effect). The probability of shrub mortality was inversely related to coppice biomass with smaller coppices clearly more vulnerable to the added pressure imposed by secondary chemical treatment, independent of application rate.

**Notes:** Concludes that the method showed enough promise to warrant further investigation. Introduction outlines use of fire and difficulties. The use of chemicals has also been tried in US rangelands


**Abstract:** Summary: It is postulated that cost-effective control strategies for resprouting shrubs can be developed by integrating strategically timed defoliations imposed initially by prescribed fire followed by chemical defoliation. The hypothesis proposes that secondary defoliation of young coppice growth using sub-lethal applications of environmentally acceptable chemicals, must be undertaken in the autumn no later than one year after fire. Preliminary results in terms of chemical activity are extremely promising even though these sprays were applied to five-year old coppice of two resprouting species. Two months after application significant defoliation had been achieved with several chemicals applied at half the concentration normally recommended for root kill of woody species. At lower rates
defoliation was still increasing 6 months after treatment, presumably through gradual translocation.


Abstract: Irregular fire defines a fire regime with an unpredictable frequency pattern, a pattern characteristic of most Australian semi-arid and arid rangelands. The unpredictability stems from the vegetation characteristic of failing to produce sufficient fuel to carry a fire except in response to unusually wet climatic events. Although the mean frequency of fire is usually low, multiple fire events may occur over a period of a few years under the influence of a rare climatic sequence. Thus large scale fires in Australian rangelands follow above-average rainfall seasons. This contrasts strongly with the more humid sclerophyll forests where wildfires only occur during droughts. Most rangeland communities are resilient to fire but are not necessarily stable and significant changes in structure and composition may occur. Such changes are not due to fire alone because the interaction of grazing pressure and rainfall regime before and after the fires determine the overall ecological impact. Grazing pressure can both affect and interact with fire regime by reducing the quantity of fuel and by changing the plant species composition.

Notes: Large scale fires in Australian rangelands generally follow seasons when above-average rainfall has been recorded - correlation between total number of wildfires and 2 or 3 years of antecedent rainfall. This contrasts with fires in humid eucalypt sclerophyll forests where wildfire seasons generally follow droughts. Rainfall patterns following a fire event will dictate what plant species germinate and establish successfully. Herbivore grazing pressure will also significantly influence the quantity of fuel available as well as the quantity and composition of the developing post-fire vegetation. Sprouters v’s non sprouters and age of plant critical in result of burning. Provides useful diagram of interacting factors in vegetation response in a mallee/Triodia community. A patch dynamics approach to rangeland ecology may be useful for describing post-fire rangeland regeneration. In this plant communities are seen as largely non-equilibrium assemblages in which gaps produced by single or multiple fire effects are filled through opportunism and evolved differences in reproductive strategy. Rather than an orderly predictable and linear progression to an idealised climax, plant communities might be seen as strongly conditioned by disturbances and the opportunistic response to the disturbance.

Abstract: Prior to European settlement, medium-sized marsupials, especially bettongs (*Bettongia* spp.), were widely distributed across arid and semi-arid Australia. Most disappeared rapidly in the late 1800s in the earliest settled rangelands such as the West Darling region of western New South Wales following the spread of domestic herbivores, rabbit invasion, exotic predators and loss of habitat. Because the burrowing bettong (*Bettongia lesueur*) is the only fossorial macropod species, it left a clearly visible record of its past presence, distribution and habitat preferences in the form of substantial relict warrens, particularly in stony, ‘hard-red’ habitats.

With the reduction in fire frequency because of excessive grazing pressures following European settlement in the 19th century, there was a rapid increase in the density of unpalatable native shrubs. We examine the hypothesis that periodic wildfires and browsing by bettongs were together able to regulate shrub densities in semi-arid rangelands in Australia. Information from various sources concerning the effects of fire, rainfall and browsing on the demography of shrubs was used to construct a model of shrub population dynamics. The model indicates the potential for two states for a given bettong density: first, a low shrub density maintained by a combination of periodic fire and bettong browsing; and second, a high shrub density in the absence of fire. These results have broad implications for pastoral and conservation management in Australian semi-arid rangelands.

Notes: The results of the model suggest that shrub population regulation in the past, especially on a regional scale may have depended on episodic fire followed by mesomarsupial browsing of shrub regeneration.


Abstract: Soil acari have been found to play an essential role in decomposition and mineralisation processes in arid ecosystems. Some preliminary surveys of soil acari in several habitats in western NSW were undertaken to evaluate the degree of similarity or difference in these systems with those studied intensively in North America. We also compared samples from a mallee area that had been burnt in March 1987 with those from an adjacent control area that had not been burnt for at least 60 years. There were more mites in the unburnt area. The reduction of mites in the burnt area is consistent with findings of Moulton in sandstone forests south of Sydney. Burning reduces the organic matter in the upper soil layers which reduces the energy source for the microflora on which the microfauna depends. While the soil microfauna play an important role in nutrient mineralisation in arid soil systems in extreme nutrient limited systems like the Australian mallee the benefits of the pulse of nutrients released by burning far exceeds the potential loss of mineralisation by the reduced soil fauna. In mallee ecosystems it is highly likely that the soil biota cannot decompose and mineralise...
dead plant materials at a sufficiently high rate to keep up with the nutrient requirements for optimal vegetative growth.


**Abstract:** This paper describes experiments undertaken at several sites in semi-arid woodlands of eastern Australia to determine if chemicals applied either on the ground or from the air reduce the density of shrubs regenerating after disturbance. Ground-spraying of Roundup® in the autumn was more effective than spring application in defoliating shrubs, especially 2-year-old coppice growth. Spraying of Roundup with a hand-held boom at 0.5 up to 2.5 kg glyphosate/ha identified rates to be used for boom spraying. Aerial spraying experiments were then undertaken across several sites and involved several target species. The location of sufficiently large areas where shrub regeneration was of an optimum age (i.e. about 2–3 years) proved to be extremely difficult due to prevailing drought conditions precluding the use of prescribed fire as a preliminary treatment. Nonetheless in one experiment, young (1-year-old) regrowth of firebush (*Senna pleurocarpa*) exhibited increased sensitivity to Roundup with significant shoot mortality recorded after it had been applied at 0.5 kg glyphosate/ha. Aerial spraying based on an ultra-low volume application of 10 L/ha further enhanced cost-effectiveness on this occasion. Economic analyses structured around 20-year partial budgeting and determination of net present value (NPV) suggested a profitable return could be expected where treatment was based on Roundup applied at this threshold rate 2 years after a prescribed fire, especially when the rehabilitation costs were spread over an entire paddock that had been only partially sprayed. Finally, operational aspects involving aerial spraying in these semi-arid woodlands are also discussed.

**Notes:** Prescribed fire is considered the most cost-effective option for shrub control on economic criteria but it is severely limited by unreliability of herbage fuel which is driven by antecedent rainfall. The use of other control options has been severely constrained by high costs. Foliar sprays at low concentrations might mimic annual fires.


**Abstract:** This article describes the effects of the 1974-75 wildfires on the mallee vegetation in the Western Division of New South Wales using two properties as case studies. The management implications arising from these experiences are described in some detail, particularly the potential for some form of management based on periodic prescribed burning to promote herbage productivity and also to reduce any future wildfire hazard. The need for appropriate research to be undertaken in this field is also discussed.
Notes: Assessment of impact of 1974-5 fires in mallee on 2 properties near Pooncarie. Of 3.74 mill ha burnt half was mallee. Description of characteristics of mallee. Management implications: need for access & firebreaks, prescribed burning. Triodia mallee burnable during droughts and produces good herbage growth - experimental burn in 1977 produced herbage in following wet period but not in unburnt mallee. Open mallee only burnable when speargrass present for fuel. Frequency depends on conditions. Post-fire grazing management important.


Abstract: The probability of wildfires, or prescribed fires, occurring in mallee rangelands, is strongly dependent on availability of adequate grass fuel loads. Grass fuels comprise two major elements, a perennial component dominated by the hummock species Triodia scariosa (porcupine grass) and an ephemeral component dominated by the annual/biennial tussock species Stipa nitida (speargrass). Population dynamics and abundance of both fuel elements are, in turn, strongly influenced by rainfall regime, particularly during the seedling recruitment phase. This paper records data on the spatial distributions of different fuels, plant architecture and post-fire seedling recruitment and survivorship of T. scariosa, obtained during field studies on contrasting mallee sites in western New South Wales. In addition, rainfall data extending over c. 100 years were used in a water balance study at one mallee site (Pooncarie); while similar rainfall data were analysed for three mallee sites (Pooncarie, Ivanhoe and Mount Hope) using a filter technique to examine quasi-periodicities of rainfall and potential correlations with known wildfire seasons in the past. Precipitation records from the Meteorological Districts of western New South Wales, and from various towns in the area, were analysed as well. All data sets exhibited strong coherence and the resulting filter curves resembled each other closely, with peaks reflecting 'above-average rainfall' and troughs 'below-average rainfall or drought'- the latter often being associated with El Nino-Southern Oscillation events. The management implications of these phenomena, particularly as they relate to major drought events, are discussed in the context of vegetation manipulation based on prescribed fire.

Notes: Analysis of the occurrence of wildfires in mallee and the conditions needed for them to carry. Mallee wildfires occur after above average rainfall and depend on the growth of ephemeral herbage as fuel e.g. speargrass which links perennial fuels and triodia clumps; conversely sclerophyll forest wildfires occur after drought years and depend on perennial fuels e.g. eucalyptus litter and leguminous shrubs. Need to understand the fuel-climate intersections to develop fire management plans. Fire, grazing and rainfall are the major perturbations that regulate vegetation dynamics in arid, semi-arid rangeland systems - interactions produce a synergistic effect. Only fire and grazing are amenable to management as ecological stimuli (Noy Meir 1973, Westoby 1979/80, Wilson et al 1988). Rainfall periodicity
analysed and it is not as unpredictable as generally thought. Paper analyses dynamics of ephemeral & perennial grass fuels at Taraw i & Scotia in SW NSW. Determined that there appears to have been a 15-20 year fire periodicity. Provides detailed discussion of rainfall patterns. On the basis of 10 years of data Griffin et al (1982) found wildfire occurrence closely related to 3 years antecedent rainfall, area burnt related to 2 years antecedent rainfall. In NW NSW Harrington (1991) used WATBAL to analyse 97 years rainfall for wooded grasslands near Yantabulla.


Abstract: The idealised view of good range management in an agricultural context is 'sustained maximum yield' of some animal product. The word 'sustained' implies that the range can be utilised in such a way that yield remains more or less constant from year to year. Nevertheless, managing for maximum yield in the short term can lead to gradual or sudden changes in the range which reduces yield for a long time. Such reductions in yield are inevitably associated with either a change in species composition (which may be invasion by (or increase in) woody shrubs/trees or an increase in the proportion of unpalatable grasses) or a change in the stability of herbage production. Such changes impinge on hypotheses about stability and resilience. The question addressed here is how can range stability and resilience be estimated or measured? The problems are examined together with ways in which they might be analysed. Herbage production is used to discuss possible empirical definitions of stability and resilience and in turn is applied to various sets of experimental data from Israel and southern Africa.

Notes: If African rangelands are subject to periodic light grazing, palatable species predominate. If grazed continuously and fairly heavily they give way to unpalatable species - is it a single stable equilibrium or multiple equilibrium condition? In attempting to interpret the relative dynamics of palatable and unpalatable grasses time scale (after removal of grazing one species returned in 8 years, another in 13 years but if reassessed in 5 a change of state would have been concluded), phenological differences (different species are favoured by different patterns of seasonal rainfall - early grass rains, later shrub rains - seasonal distribution of rain overrode any differences in grazing pressure) and response to grazing all need to be taken into account.


Notes: Results from a vegetation and fauna survey in the Cobar Peneplain of western NSW.
Communities surveyed include Belah woodlands, mallee woodlands, white cypress pine woodlands, riverine woodlands and mulga shrublands.


**Notes:** General information booklet covering: How fire behaves (How fire starts, effects of wind & slope, fire intensity, fire regimes, fire & future climate), History of fire in Australia (Before human occupation, since human occupation), managing fire in NSW (Managing fire regimes). Evolving is a fiery environment: How plants respond to fire (seeders, seeds protected on the plant, stored in soil, sprouters, buds protected underbark & underground, flowering after fire); Impact of fire on animals (during the fire, after the fire, changed behaviour, post fire predation, hollows, patterns of population recovery. Influence of the fire regime.


**Abstract:**

**Notes:** Ch 1: Overview of planning for bushfire protection
Ch 2: Bushfire protection and the Planning system
Ch 3: Addressing bushfire issues in Local Environment Plans
Ch 4: Bushfire provisions - development stage
Ch 5: Construction standards for bushfire protection
Ch 6: Preparing for bushfire hazards and maintenance


**Notes:** High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition was listed as a KEY THREATENING PROCESS on Schedule 3 of the Threatened Species Conservation Act 1995 [24 March 2000].

Plants and animals have a range of mechanisms to survive individual fires. The long-term survival of plants and animals over repeated fires is dependent upon two key features:

- the ability of species to maintain life cycle processes; and
- the maintenance of vegetation structure over time as habitat for animal species.

Where fires occur very close together in time (high frequency fire) both these key features can be disrupted. If high frequency fire is sustained it will consequently lead to a loss of plant species, a reduction in vegetation structure and a corresponding loss of animal species. A high frequency of burning can eliminate some species if they are burnt before they seed (DEH 1994).
High frequency fire and inappropriate fire regimes have been identified as threats to a number of species and communities including:

Plants - Acacia binyoeana, Acacia courtii, Acacia macnuttiana, Acacia pubifolia, Acacia ruppii, Acrophyllum australe, Almaleea cambagei, Apatophyllum constablei, Asterolasia elegans, Boronia granitica, Boronia repandra, Calitris oblonga, Cynanchum elegans, Darwinia biflora, Elaeocarpus williamsianus, Eucalyptus nicholii, Grevillea banyabba, Grevillea beadleana, Grevillea caleyi Grevillea mollis, Grevillea rivularis, Grevillea scortechinii ssp. sarmentose, Grevillea shireseii, Haloragodendron lucasii, Homaranthus lunatus, Lasiopetalum joyceae, Leptospermum thompsonii, Melichrus hirsutus, Phaius australis, Phaius tancarvilliae, Phebalium glandulosum ssp. eglandulosum, Phebalium lachnadeoides, Pimelea spicata, Pterostylis gibbosa, Pultenaea sp. Olinda, Styphelia perileuca, Swainsona plagiotropis, Velleia perfoliate, Zieria involucrata.

Birds - Glossy Black-Cockatoo, Eastern Bristlebird, Mallee Fowl, Ground Parrot.


Ecological Communities - Ben Halls Gap National Park Sphagnum Moss Cool Temperate Rainforest, Duffys Forest, Eastern Suburbs Banksia Scrub, Kurnell Dune Forest, O’Hares Creek Shale Forest, Pittwater Spotted Gum Forest, Other listed endangered ecological communities, including Cumberland Plain Woodland, Sydney Turpentine Ironbark Forest, Blue Gum High Forest, Elderslie Banksia Scrub Forest, Genowlan Point Allocasuarina nana heathland, Sydney Coastal River-flat Forest, Shale/Sandstone Transition Forest and Cooks River Clay Plain Scrub Forest are all likely to suffer a loss of species composition if subject to repeated high frequency fires.


**Abstract:** Fire is part of Australia’s heritage - it has and continues to shape much of our natural world. Historically a fine-scale mosaic of different aged burns predominated, but since the early 20th century there has been an increase in hotter, extensive fires, more threatening from both a human and biodiversity perspective. Such inappropriate fire regimes, including the exclusion of fire, threaten over 50 bird species and subspecies and, since European settlement, have contributed to the extinction of two species. Yet inappropriate management of fire is one of the most tractable of the major threats to Australian wildlife. To some extent the old adage ‘fight fire with fire’ applies. Used well, fire is an effective, economical tool for land managers. Reintroduction of occasional fire into some landscapes, and return to a finer mosaic of burning, will not prevent wildfires; it may, however, reduce their impact, by maintaining fire-dependent habitat and protecting fire-dependent birds. There will always be uncertainty, but by striving for practical and effective fire management objectives we can better manage the risks to both human life and property and biodiversity.

**Notes:** Biodiversity loss is associated with high fire frequency, intense broadscale fire and fire
exclusion, all of which tend to homogenise the landscape. Increasing loss of habitat heterogeneity from the landscape is the single most damaging effect of poor fire management. Birds most threatened by inappropriate fire management occur in coastal heath, mallee and northern grasslands and woodlands. Maintaining a mosaic of habitats of different fire ages is recommended for large area fire management, but where habitats are small, fragmented and isolated the options are fewer and issues more complex. Fire management must be ongoing and adequately resourced.

Tarawi semi-arid mallet in NSW: ensure consecutive fires are at least 20 years apart in any one area; ensure a range of post-fire ages are present in the reserve (at least 50% of each mallee community should be >40 years old) to promote patchiness in wildfires - scale not specified due to lack of knowledge; burn strategically to contain the spread of wildfires that may violate the thresholds for fire frequency, post-fire age diversity or patchiness requirements. Threatened mallee birds affected by inappropriate fire management: Malleefowl, mallee emu-wren, Black Eared Miner, Western Whipbird. Discusses fire in the tropical savannas, arid central Australia (Newhaven), south west WA, mallee heathlands of Ngarkat, SE NSW (Nadgee).


Abstract: Satellite remote sensing provides a relatively rapid and cost effective means of mapping the physical and biological resources of large areas. Landsat multi-spectral scanner digital imagery was used to map soils, vegetation and erosion in a semi-arid area of south-western NSW. The classified image showed strong agreement with independently mapped soil boundaries. The technique developed is suitable for identifying and mapping areas affected by fire, overgrazing, erosion, land clearing and cultivation. With an increased awareness of ecologically-based landuse practices, the use of remote sensing for monitoring changes in land use and land degradation is likely to increase.

Notes: Adequate management of this region requires information on landforms, soils, soil erosion, vegetation type and condition and regular collection of data to determine what changes may be occurring to the land resources and whether they are deleterious.


Abstract: Discusses: Geography; Characteristics (landforms; soils; water supplies; trees and shrubs; pastures; pasture dynamics; pasture resilience); Utilisation of Vegetation (animal diet selection; animal productivity); pastoralism (nature of industries, productivity and

Abstract: Summary of talk at the seminar 'Management of Shrub Infested Rangelands - Bourke April 1985.
Prescribed burning is a management strategy which can maintain or increase productivity on shrub infested rangelands through plant community management. Key element - early planning incorporated into overall management strategies. Graziers need to become familiar with the plant communities and to recognise a germination event as it happens and not 5 years later when sheep can't be seen. Grazing must be managed in advance to enable a successful burn to justify all the preparation.
Fire danger index: measure of fire intensity and rate of fire spread - determined from temperature, humidity, wind speed, fuel type and amount. But need to remember the aims of prescribed burning - to achieve high shrub mortality and a large burn out of the paddock - creates a trade off between cost, safety and results. Winter fires may be cheap and easy but may not meet the aims while summer fires may meet the aims at greater cost.
Must have equipment in top working order - breakouts can then be controlled - tanks, pumps and hoses are the usual causes of problems.
Procedures - map areas and identify key positions on the ground, enable easy communication and identification of units, give each unit a copy of the map of the burn area, ensure communication network is operative, ensure everyone knows their role.


Abstract: Fires were once a natural occurrence in mixed mesquite/acacia (Prosopis, Acacia) shrublands of southern North America. Fire frequency has decreased over the last 150 years due to the reduction in fine fuel and to fire control. Where fires are used for shrub management, prescribed burns are conducted during the cool winter months when the possibility of losing control of the fire is low. There is growing evidence however that the seasonality of fires can alter plant species composition and community architecture. Fires conducted during the dormant season may favour dominance by C₄ grasses but growing season fires may promote herbaceous species diversity.
Reintroducing growing season fires into mesquite/mixed acacia shrublands did not conclusively alter plant community composition. Change from short grass dominance to tallgrass dominance was evident in both burned and unburned plots, but the rate of change seemed to be greater in the burned plots. Burning during the growing season when
environmental conditions were hotter and drier did not accelerate changes to grass dominated communities.


**Abstract:** This article examines historical records of a grazing property in south-western Queensland to analyse various aspects of station improvements, pasture and sheep productivity. The drought at about the turn of the century was the catalyst that led to a permanent loss of pasture and carrying capacity. Competition from rabbits and the full utilisation of grazing land by about 1914 exacerbated the situation. The station was able to cope with early localised degradation because new land was constantly becoming available due to improvements in fencing and stock watering facilities. Summer rainfall was of utmost importance in providing sufficient perennial grass for the maintenance of stock numbers. Annual sheep losses and average fleece weights were highly correlated with the amount of summer rainfall. A high lambing percentage was dependent on good seasonal conditions—over the 18 months.

**Notes:** Drought at the turn of the century was the catalyst that led to the permanent loss of pasture & carrying capacity.


**Abstract:** This article combines data from historical records, recently published maps and a field survey to document changes in the vegetation of a pastoral area in south-western Queensland. Examples are given where wildfire, ringbarking, clearing and grazing by both rabbits and domestic stock have had major influences on the vegetation. The greatest change to the trees and inedible shrubs has been one of density. Evidence for changes in the herbaceous layer is less conclusive but it is likely that there has been a reduction in density of desirable perennial grasses and an increase in less palatable species.

**Notes:** 1901 land unit/vegetation map of the Thurulgoona property in SW Qld compared with vegetation in 1985. Subtle vegetation changes occur continuously (successional change) but rapid change occurs with management practices &/or episodic events. Mulga removed by management - cut for drought feed and no regeneration due to grazing and drought. No evidence for mulga invasion of grassland. Major reduction in Old man saltbush

Zoological Society of New South Wales, Mosman, Sydney.

Abstract: The Western Division of NSW occupies an area of 32 million ha, being the most arid 40% of the State with average annual rainfall ranging from 475mm in the north-east corner to 150mm in the far north-west corner. Pastoral settlement took place in the period between the 1830s and the late 1870s. Along with the adjoining area in South Australia, the land and the vegetative resource was devastated over a large percentage of the area by the combination of rabbit plagues, high stock numbers, severe economic depression and prolonged drought at the turn of the century. Evidence to the Royal Commission of 1901 provides a graphic description of huge areas windswept and scalded, with sand drift covering fences, water troughs, stockyards and even silting up earthen tanks. Extensive areas of perennial shrubs, the saltbushes and bluebushes, often on the more erodible soils, were wiped out. However a combination of influences dating from the early 1950s has brought about a remarkable recovery, with most seriously eroded areas now regenerated, with parallel improvement in the recovery of perennial grasses and shrubs. However the reappearance of the rabbit, the invasion of much of the northern half of the region by woody weeds and the destruction of small native animals and birds by foxes and feral cats, and the destruction of habitat by feral pigs and goats, will reduce the benefits of this recovery unless these adverse factors can be brought under control.

Notes: Outlines the historical changes and then describes the 'recovery' that occurred between the 1940s and the 1990s. Well 70km west of Ivanhoe - nothing growing for several kms around the well in 1940s & 1950s - now the whole area covered with groundcover and soil is accumulating in former scalds, rills and gullies no longer active. Dense bluebush regeneration has occurred - remarkable change in 40 years with high numbers of both sheep and kangaroos.


Notes: 'Only two things keep unpalatable woody weeds in check - competition from vigorous grasses and fire.' Fire can be used to rehabilitate poor mulga grassland but only if stock maintained at reasonable carrying capacity. Fire will kill green turkey bush, narrow-leaf hopbush and fernleaf hopbush when they are small but they will return after good rainfall from seed. Seedlings under 15cm of grey turkey bush, turpentine and false sandalwood will be killed but more mature plants will resprout. Process of degradation: overgrazing, no fires, too much shrub regrowth, less groundcover, erosion & surface sealing, increased runoff finally
producing bare soil under mulga thickets or total turkey bush. 

Rehabilitation: begin by using machinery then take a more ecological approach: reduce TGP; pull mulga in one paddock; destock this paddock for one good season, allowing grasses to grow and seed; burn paddock if regrowth a problem; allow grasses to grow and seed again; restock to carrying capacity, browse to keep mulga below 170 stems per ha; continue with burning and conservative grazing. Conditions etc specified but these are based on reasonable rainfall - frequency 1 in 5 years.


Abstract: Mallee vegetation originally covered some 22000sq km or 7% of the western division of NSW. Occurs on a variety of soils in the winter rainfall area. Over the last 25 years about 11% has been cleared, 8% is dedicated as National Park or reserve. This discussion paper considers the questions of conservation v's cultivation and proposes some resolutions to this difference in perceptions including 12 recommendations. Nature conservation aside, the most critical effect of clearing mallee is to exacerbate land salinisation. Mallee communities were adapted to a particular fire regime that no longer exists. Prescribed burning for hazard reduction is not an ecological substitute for the original, occasional wildfires. However it is perhaps the only tool available to manage the density of mallee, and such native pastures that exist. Prescribed burning should be recognised as a legitimate method of rangelands management. Unless sufficient fuel is present the mallee will not burn. This limits most prescribed burning operations to intervals which will probably not change the communities. More frequent burning should be regarded as a clearing operation.

The conservation of mallee is the responsibility of the NPWS who should undertake the necessary surveys to determine which areas warrant acquisition and dedication. The conflict between development and conservation affects the whole community. Changing social values and perceptions are reflected in increasing demands for conservation. If society that landholders refrain from clearing, then society should be prepared to carry some of the financial burden. Taxation relief is probably the simplest and most equitable way of achieving this.

Notes: Some of the 12 recommendations:
6. Individual prescribed burning operations >5000ha should require an EIS
7. Prescribed burning operations in close succession on the same area should be regarded as clearing rather than hazard reduction techniques.
8. Prescribed burning operations greater than 10 year intervals and involving areas <5000ha should be exempted from the need for a clearing licence (reg 50 WLAct)
Includes useful series of maps with mallee distribution in SW NSW, incidence of fires, soil types, land tenure etc.

Wales: Notes to accompany the 1:1,000,000 vegetation mapsheet. *Cunninghamia* 3, 423-64.

**Abstract:** The pre-settlement vegetation of the north-western quarter of New South Wales (latitude 29-33 degrees South, longitude 141-147 degrees East) is interpreted and mapped at the Australian continental scale of 1:1,000,000. The area (approximately 26.6 million ha) represents 28% of the State and is mostly within the Western Division. The map shows 41 plant communities, defined by structure and characteristic plant communities, and 28 mosaic communities. Brief descriptions are provided in the text. Vegetation is predominantly controlled by climatic and edaphic factors. The area covers much of semi-arid NSW. Potential problems in vegetation management and conservation options are discussed.

**Notes:** What is considered acceptable damage to the landscape and what levels of stocking are acceptable? Graziers are probably unlikely to recognise the subtle changes that have taken place. Everyone can see and understand the impact of scalds and woody weed invasion but how many graziers are aware that losing the top 5cm of soil in mulga results in the loss of the bulk of the nutrients? Woody weeds: general belief that density increase due to absence of fire - domestic stock have remove all the available fuel so these plants are responding to a radically changed environment as a consequence of grazing. Evidence from Texas also suggests that these woody increase are a response to increased CO2 levels since the mid 19th century.


**Abstract:** Thinning or complete clearing of dense mulga (*Acacia aneura*) woodlands in south western Queensland may lead to undesirable rangeland conditions unless sound property management is practised. Even ten years after thinning, ground storey vegetation in an ungrazed situation is still in a state of flux. Livestock management following clearing can markedly influence pasture composition and mulga regeneration. Poor rangeland management may lead to reductions in pasture basal area sufficient to reduce productivity and accelerate degeneration through soil and nutrient losses in run-off waters.

**Notes:** Management of mulga lands is complex: desirable v's 'undesirable' groundstorey, tree v's ground layer, low & variable rainfall, extreme temps, infertile soils and can grow in dense forests (>8000/ha Charleville area), also important as fodder. Removal of shrubs recommended for herbage production but what are the long term effects on herbage quality, evapotranspiration, runoff & stability of the system? Herbage dependant on grazing intensity, ground layer not stable after 10 years, evapotranspiration not as reduced as anticipated, loss in ground cover leads to increased runoff & loss of surface soil and nutrients leaving decreased pasture production. important to maintain a balance between cleared and uncleared areas.

Abstract:
Notes: Paper focuses on the strong ecological and production oriented reasons for using fire, the reticence of the grazing community to burn; the aversion of the general public to fire and that different approaches are needed to change these attitudes and perceptions. The authors believe that without fire the opportunity to maintain good condition and improve condition of grazing lands will be lost. Use of fire: to remove rank & unpalatable grass; contain size & density of woody weeds; guard against wildfire.

*Brigalow*: Timing is critical - Burning within a few months of clearing leads to excessive regrowth, excessive delay (12-18 months) reduces the amount of debris burnt. Fire also important to keep size of shrubs in check - early summer burns every 3-4 years will temporarily reduce competition between suckers and pasture but little effect on overall woody density. Herbicide sprays on post-burn regrowth produces better control. *Mitchell Grasslands and Spear Grasslands* also discussed.

*Mulga & Poplar Box*: Supports fire as a control measure - no details. Both grow on poor soils (nutritionally & physically) and sound fire management depends on understanding the ecology of the system. Low & variable rainfall also a problem.

*Fire application*: As little as 30% of the area of a burnt paddock with poor fuel loads will be actually burnt.


Abstract: Opportunistic burning of native vegetation following good rainfall seasons is one reasonably effective way of decreasing the density of some useless woody weeds growing in the mulga rangelands of Queensland. Damage to pasture species is minimal and serious post-fire loss of carrying capacity can also be minimised through judicious timing of the fire.

Notes: More than 56000 sq km of mulga country is estimated to have an existing or potential woody weed problem. Chemical treatment while effective is too costly, Goats, sheep and cattle have proven ineffective in control, fire is the remaining tool. Timing of fire is important. A fire in spring would have the advantage of killing both the mature shrubs and seedlings of *Eremophila gilesii* which may have germinated following autumn-winter rains. Such a fire would be a cool one and would have only minimal effect on the pasture species. *E bowmanni* and *E. sturtii* which regenerate following fires from basal and sometimes aerial roots may be most affected by a very hot summer fire. Maximum fuel could be needed to generate
sufficient heat to severely damage the subterranean root system. Grazing capacity could be affected.


**Abstract:** Expectations of the productivity of rangelands which are greater than can be realistically achieved are the prime cause of degradation. These case studies centred on Queensland are used to highlight the difficulties which can be expected in attempting to restore rangelands to a productive state. The need for an ecological understanding of the system is an essential prerequisite for rehabilitation. Restoration will not be successful in the long-term if management based on sound ecological principles and a change in attitude towards expectations and risk are not implemented.

**Notes:** Cause of degradation: expectations of the potential productivity from rangelands > than reality. Acceptance that higher than average rainfall and resultant pasture response is the norm is patently wrong! Use of mean rainfall is misleading. Effects of livestock depends on the stock. Rehabilitation means restoration of productivity. Fire most likely to work for the woody weed problem. An understanding of the ecology of a particular area is the only way to predict the success of potential rehabilitation strategies.


**Abstract:** Because grazing by livestock is one of the primary threats to rangeland biodiversity, but is unevenly distributed in space, rangeland monitoring programmes need to take account of the distribution of grazing pressure in order to distinguish between grazing-induced change, seasonal fluctuations and changes that are a result of other threats. Livestock watering places are one of the major influences that give spatial expression to gradations in grazing activity. Using research results from the goldfields of Western Australia, we show how distance from water can be incorporated in spatial models to predict cumulative grazing pressure at different sites within paddocks. Two surrogates of grazing activity are illustrated: one relying on a commercially available model, and one developed from measures of track density. Factors other than distance from water can also have profound effects on the distribution of grazing pressure and its impacts at landscape and regional scales, and we review some of these briefly. Finally, we outline key spatial implications for the design of rangeland monitoring programmes.

Abstract: A history of the changes that have occurred with the grazing of a piece of valuable flood-out on the property Artartinga, north-east of Alice Springs. These changes date from when the area was first stocked on 1930. It is the story of the floodout surrounding th Umberumbra waterholes and of the hill feeding the floodout. It is about the stocking history of the area and the effects that this had on the country over the years through to my present efforts to reclaim some of this floodplain. Discusses plants, especially perennial grasses that he believes would have occurred there, natural waterflow patterns etc. Accompanied by diagrams. Describes approach to reclamation using banks, strategic grazing and fire.


Notes: A general discussion of the politics of fire - both wildfire and prescribed fire. Begins by outlining a perception of 'Nature's Fire' and the coming of the firestick (anthropogenic fire) - myths re origins of human's use of fire etc. While Pyne presents a general broad theory for the use and impact of fire on vegetation and the extinction of the megafauna this is done without substantial referencing and is in disagreement with the analyses of the palynological record (eg Kershaw et al 2002) and other discussions of the loss of the megafauna. While this book is regularly referred to it is essentially the presentation of many unsubstantiated claims about the use of fire in the Australian landscape. Unfortunately the author does not provide any further substantiation and continues to make assertions that have been carefully refuted by well researched work on this topic.


Notes: Article discusses research from the Scripps Institution of Oceanography in San Deigo which has collated data from satellites, aircraft and surface instruments on the warming effect from black carbon (soot). They conclude that its effect in the atmosphere is around 0.9 watts/sq metre, higher than the estimate of 0.2-0.4 watts used for the IPCC 2007 report. The 8 million tonnes of soot released into the atmosphere annually have created 'hot spots' around the world, contributing to rising temperatures.


Abstract: The impression has been given in previous studies that there are few bird conservation problems in the arid zone, particularly because not one of a total of 230 species
has become extinct. In stark contrast, almost half of the native terrestrial mammalian fauna of the Australian arid zone has become extinct on the mainland since European occupation. Here we show that the status of one half of the avifauna has changed since European occupation, and conclude there are many threats to avian biodiversity at the regional scale in the arid zone. There are 19 species (8%) in the arid zone classified as rare and threatened nationally. Twelve more (5%) are uncommon species which have declined or are at risk in two or more regions. A further 40 species (17%) have declined in at least one arid region, although many of these remain common and some have increased elsewhere in arid Australia. At least 45 species (20%) have increased in range or abundance, including a suite of ground-feeding birds associated with degraded landscapes.

Striking patterns emerged from analysis of 29 threatened and declining species:

- birds associated with chenopod shrublands and grassy, riparian or floodplain environments have been most affected whereas mulga inhabitants and canopy-dwellers of riparian woodland have been little affected;
- birds generally with a northern distribution have declined in the south of the arid zone and birds with a southern distribution have declined in the north of the arid zone, and these patterns contrast with many birds with a southern or continental distribution which have declined more in southern semi-arid regions than within the arid zone itself;
- birds which feed at ground and low shrub height have been most adversely affected;
- sedentary bushbirds (passerines) are more at risk than nomads and their limited mobility seems to be a risk factor;
- among non-passerines, parrots, cockatoos and pigeons are most at risk, while three passerine families stand out, namely wrens, quail-thrushes, and thornbills and allies;
- contrary to findings for mammals, size does not generally appear to be an important risk factor.

Land degradation and habitat alteration such as shifts in abundance or dominance of plant species caused by the introduction of exotic herbivores appear to be the principal factors causing change in status while the provision of reliable water sources in pastoral districts is also important. Introduced predators are implicated in some cases and altered fire regimes may have played a part in spinifex and mallee habitats. Competitive interactions between increasing and declining species, although not demonstrated, appear to be likely for some species.

We have documented a hitherto unsuspected degree of change in avian biodiversity in the Australian arid zone. In the absence of widespread regeneration of dominant plant species in the southern arid zone, the decline of many arid birds will accelerate dramatically. Also, unless better management ensues the next major drought could cause accelerated declines and extinctions. We advocate a range of measures designed to improve the conservation prospects for arid Australian birds, including lower stocking rates on pastoral properties, rehabilitation of critical habitats and their protection from exotic herbivores, experimental research on the impact of grazing and predation, and monitoring of both threatened species and a range of sedentary passerines typically associated with representative habitats in the arid zone.

Notes: Western NSW - the situation is more severe in semi-arid NSW than in the state's arid north west and the plight of birds in NSW arid NW is worse than in pastoral WA. Altered fire
regimes do not appear to have had a direct impact


**Abstract:** *Extract from summary:* Major aim of the survey was to gather information about the functional processes that give rise to the patterns of distribution and to offer management advice based on that understanding. Mammal, bird and reptile communities were found to be especially dynamic in the spinifex dominated landscapes with the communities on the 4 harder sites more stable through time. Fire is an important structuring force in spinifex grasslands. Recently burnt areas are favoured by nomadic birds, some small mammals and a few reptiles. A few birds and small mammals and many reptile species are largely restricted to mature spinifex. Fire is a manageable dynamic force but further information is required to allow management to make more informed decisions about the use of fire as a management tool, in particular with regard to its effect on fauna. The overall direction and objectives of the currently implemented patch-burn strategy, as advocated by the traditional owners and previous scientific research alike are supported by the results from this survey.


**Abstract:** Disturbance events strongly influence the dynamics of plant and animal populations within nature reserves. Although many models predict the patterns of succession following a disturbance event, it is often unclear how these models can be used to help make management decisions about disturbances. In this paper we consider the problem of managing fire in Ngarkat Conservation Park (CP), South Australia, Australia. We present a mathematical model of community succession following a fire disturbance event. Ngarkat CP is a key habitat for several nationally rare and threatened species of birds, and because these species prefer different successional communities, we assume that the primary management objective is to maintain community diversity within the park. More specifically, the aim of management is to keep at least a certain fraction of the park, (e.g. 20%), in each of three successional stages. We assume that each year a manager may do one of the following: let wildfires burn unhindered, fight wildfires, or perform controlled burns. We apply stochastic dynamic programming to identify which of these three strategies is optimal, i.e., the one most likely to promote community diversity. Model results indicate that the optimal management strategy depends on the current state of the park, the cost associated with each strategy, and the time frame over which the manager has set his/her goal.

**Notes:** Managers of reserves have some control over disturbances (e.g. suppress fires or initiate burns) so it is important that management decisions are well planned and potential
impacts on population dynamics of threatened species are identified. Well defined management objectives must be determined. When different species prefer different successional communities - essential to ensure that communities are diverse. A single strategy may not always be the best for achieving management objectives and the best strategy may change as the state of the system changes. This paper addresses the question of when fires should be fought and when management burns should be implemented.


Notes: Rotational burning - being suggested for use in Mallee to prevent large bushfires. Has been used in many types of country prone to bush encroachment in sub-tropical South Africa and Rhodesian bushveld for a long time. 4 yearly burning has been a standard official recommendation for 30 years in many regions. It has been the basis of wildlife management in the Kruger National Park since the 1940s where a patchwork of blocks spread throughout the game reserve is burnt every year. Needs to be combined with management decisions re stocking rates, livestock type, time between burn and grazing, all controlled by drought and natural fires. Fire and goats are seen as useful scrub control agents - favours more fire and less goats as mismanaged goats are a disaster in our fragile dry country.


Abstract: Eucalyptus populinea (poplar or bimble box) can be controlled by ringbarking, mechanical pulling and by direct chemical application; fire alone has little effect. The initial ringbarking usually kills only a small percentage of trees, but repeated removal of the coppice growth leads to a complete kill. Mechanical pulling under favourable soil moisture conditions can remove many of the lignotubers from the ground and Little regrowth occurs, but in dry soils the trees break off at or near ground level and profuse re- growth occurs from the broken stumps. Chemical injection treatment, using the picloram compounds or 2,4,5-T, is probably the most economical method and high percentage kills can be obtained under all seasonal conditions. Of the shrub associates of poplar box, Eremophila mitchellii can be effectively controlled by basal stem sprays of 1.0% butyl 2,4,5-T in diesel distillate, whilst shrubs such as Cassia nemophila, C. artemisiodides and Acacia deanei have been shown to be susceptible to fire under suitable fuel loads. Other important shrub species have reacted in varying degrees to both chemical and fire treatment.


Abstract: Inedible native shrubs are considered to be a primary cause of lost pastoral
productivity in the semi-arid woodlands of north-western New South Wales. Most rehabilitation programs have focussed on reducing shrub density. In recent years blade-ploughs have been tested for this purpose. Results have been variable and most programs have brought neither lasting shrub control nor improved production for pastoralism over the medium to long term. Failure to control grazing after initial treatment is suspected as one reason for the low success rate. An experiment involving blade-ploughing and grazing exclusion was established in July 1990 in sandplains supporting semi-arid woodlands, near Bourke New South Wales (NSW). The treatment factors were crossed and each was imposed at two levels: present and absent. Shrub density, pasture composition and pasture biomass variables were selected and measured before, and over a 30 month period following treatment. Data were analysed using repeated measures ANOVA. The densities of *Eremophila sturtii*, *E. deserti*, *E. gilesii* and *Dodonaea viscosa ssp. angustissima* as well as that of 'Total shrubs', all increased after ploughing, irrespective of the presence or absence of grazing. In all cases except that of *E. sturtii*, there was no significant difference between shrub density in ploughed and unploughed plots 30 months after treatment. While *E. sturtii* density increased significantly to begin with, it remained significantly lower in ploughed plots compared to unploughed plots at the end of the study period. This suggests that blade-ploughing offered only temporary control of these shrubs on this land type. Pasture biomass was significantly greater in ploughed/ungrazed plots (1300 kg/ha) compared with other treatments at the end of the study. Ploughed/ungrazed plots were the only ones where fuel had accumulated to a level which offered any possibility of burning to control shrub regeneration. The same treatment also contained a significantly greater proportion of desirable pasture species than any other treatment at the end of the study period.

**Notes:** Study of effect of blade-ploughing on woody shrubs on a property near Bourke. When intending to re-establish productivity through shrub control the difficulty of establishing pasture & importance of controlling grazing is frequently overlooked. Total shrub density remained significantly lower in ploughed than unploughed paddocks but unless >95% mortality occurs over a long time period there is little ultimate effect. Blade-ploughing only controlled shrubs in the short term. One-off treatments whether mechanical of fire are unlikely to provide long term effects. Blade-ploughing followed by grazing exclusion was the best treatment combination.

**Rodda G. (1978) 1975 bushfires in northern Scotia country and their aftermath. Range Management Newsletter 78/1.**

**Notes:** In late Jan 1975 the northern section of Scotia country (Mallee) was like most of the western division of NSW that year, subjected to a series of extensive bushfires started by lightning strikes. Edible trees and bushes (Heterodendron, Myoporum, Yarran and some Cassias) appeared to be killed but resprouted in the following months. 'Rubbish bushes' (turpentine & hopbush): hopbush when burnt properly were killed but many seedlings germinated in both the burnt and unburnt country despite there being low rainfall; turpentine regrew, mainly from rootstock. Spinifex regrowth was delayed by delayed rain (8
months) which was followed by regrowth of feed; rain immediately after fire will only encourage rapid regrowth of spinifex at the expense of feed. Now looking at rotational prescribed burning on a 3-4 year rotational basis. Apart from the loss of fences the fires seem to have done a lot more good than harm in this country. Also the extreme heat generated by a summer burn in porcupine country is more useful than a late afternoon burn in May or June. Light stocking after a fire is beneficial because stock eat leaf fall and suckers which they would otherwise not get. Recognises that the timing of follow up rainfall is a critical factor.


Notes: Fire risk management
A socio-psychological view
The significance of community involvement
Community based programmes for enhancing bushfire preparedness indicate that there is considerable value in these approaches - participants are more likely to accept their own responsibility for bushfire preparedness and safety than seeing this predominantly as the authority's task. Risk awareness and knowledge regarding bushfires is higher than for other residents. In general participants evaluate community-based approaches and most of the activities included very positively - especially if the right combination of own initiative, interaction with others in the community and support from officials is established.


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Session 1: Communication amongst the players
Bush fire: Research policies and practitioners. How effective the integration. R. Rose
Overcoming the environmental impasse - overcoming the inertia. G. Douglas
How the players play in the fire management game. J. Travers

Guest Session: An Historical Perspective
The changing fire environment in Australia. P. Cheney

Session 2: Community attitudes and expectations
You don't have to live in an ashtray. D. Atkinson
Fighting fire with fire - a forester's perspective. D. Ryan
Management burning in western NSW. Green et al.
The role of the Forestry Commission in rural fire management. T. Howe
Away from the big smoke. C. Aman
Bush fire management. B. Noble

Session 3: Fuel Management and Impact Assessment
Approaches to fire management planning using information technology. N. Gellie
Prescribed fire management training. Macadamia nuts revisited?! P. Moore
Fire fuel management in Eden State Forestry District - a managers perspective. D. Ridley
Wildfire threat analysis - an effective decision support system for fire protection planning. C. Muller

Session 4: Research and trends in Fire Management
Fire management for conservation of native plant diversity. Ross Bradstock
Markov and semi-markov modelling of spatial effects of fire. B. Lord
The use of plants to minimise risk of bush fire damage to buildings. C. Bellamy
Prescribed burning in coastal regrowth E. sieberi forest. J. Gould

Session 5: Effective land use planning and development control systems for bush fire protection
Access - a major asset in fire management. C. O'Brien
Rural fire hazard assessment. R. McRae

Session 6: The need for bushfire protection in the urban-bushland interface
Hazard reduction burning - the Tasmanian experience. J. Gledhill
Can bushfires be prevented? A case for redefining the issue and changing the culture. Ted Weir.


Abstract: Fire affects all aspects of the ecology of the savannas - plants, plant communities, animals and their habitats, nutrients, water catchments and down-stream hydrology. In order to maintain savanna species diversity at landscape scales, an ideal fire regime requires the development of a fine scale mosaic where burnt patches represent a range of fire intensities and fire ages - from recently burnt through to long unburnt. All land managers need to understand the ecological consequences of fire management.

Notes: Different plant strategies for fire survival described.
Woody thickening in the VRD: Earliest known photos taken 10 years after European settlement - comparison with conditions now demonstrate that there has been a considerable increase in tree cover in riverine environments, begun or accelerated post war. Changes in vegetation on other landforms are far less evident although the general trend appears to be a slight increase
Work by Fensham and Holman suggests that the broadscale conversion from grassland and open woodland to forest is overstated. Stocks of woody vegetation can undergo considerable flux but what are they caused by? Droughts and aboriginal fire management are both implicated in these fluxes. Seed eating birds declining in the tropical savannas probably due to a combination of grazing and fire impacts. Emus also reducing in number. Discusses other winners and losers including vertebrates and invertebrates. A fire regime that will optimise animal diversity requires variety and variability, preferably at a fine scale so individuals can pick and choose areas that meet their various requirements in the huge frequently burnt areas that characterise much of the savanna landscape today, need to retain and sustain some long unburnt areas and allow others to develop. In the rarely burnt prime pastoral lands of central Qld, the Barkly Tablelands and VRD we need to reintroduce some burning.


Abstract: Considerable research has been undertaken over the past two decades to apply remote sensing to the study of fire regimes across the savannas of northern Australia. This work has focused on two spatial scales of imagery resolution: coarse-resolution NOAA-AVHRR imagery for savanna-wide assessments both of the daily distribution of fires ('hot spots'), and cumulative mapping of burnt areas ('fire-scars') over the annual cycle; and fine-resolution Landsat imagery for undertaking detailed assessments of regional fire regimes. Importantly, substantial effort has been given to the validation of fire mapping products at both scales of resolution. At the savanna-wide scale, fire mapping activities have established that: (1) contrary to recent perception, from a national perspective the great majority of burning in any one year typically occurs in the tropical savannas; (2) the distribution of burning across the savannas is very uneven, occurring mostly in sparsely settled, higher rainfall, northern coastal and subcoastal regions (north-west Kimberley, Top End of the Northern Territory, around the Gulf of Carpentaria) across a variety of major land uses (pastoral, conservation, indigenous); whereas (3) limited burning is undertaken in regions with productive soils supporting more intensive pastoral management, particularly in Queensland; and (4) on a seasonal basis, most burning occurs in the latter half of the dry season, typically as uncontrolled wildfire. Decadal fine-resolution fire histories have also been assembled from multi-scene Landsat imagery for a number of fire-prone large properties (e.g. Kakadu and Nitmiluk National Parks) and local regions (e.g. Sturt Plateau and Victoria River District, Northern Territory). These studies have facilitated more refined description of various fire regime parameters (fire extent, seasonality, frequency, interval, patchiness) and, as dealt with elsewhere in this special issue, associated ecological assessments. This paper focuses firstly on the patterning of contemporary fire regimes across the savanna landscapes of northern Australia, and then addresses the implications of these data for our understanding of changes in fire regime since Aboriginal
occupancy, and implications of contemporary patterns on biodiversity and emerging greenhouse issues.


Notes: This paper is based on a selection of quotes from early European explorers and settlers and modern authors including Tim Flannery. They suggest that at the time of European settlement of eastern Australia the vegetation was mainly grassland and grassy woodland and most of this was burnt every year or so. A lack of fire after European settlement led to thick regrowth that was subsequently ringbarked and cleared by settlers for agricultural expansion. This paper overlooks the extensive literature on past and present vegetation and on fire ecology in Australia. This paper has been strongly refuted by Redpath and Benson (1997).


Abstract: A new compilation of data on the distributions and habitat preferences of reptiles and amphibians in the Western Division was used to determine a conservation strategy for the region. A total of 112 species of reptiles and 20 amphibians was recorded, of which 48 reptiles and eight amphibians were identified as requiring particular attention: 3 species of reptile at the national level, 27 reptiles and 3 amphibians at the state level, and 18 reptiles and 5 amphibians at the regional level. In these three geographical contexts, species of concern were definitely or tentatively allocated to five categories: four species as endangered, two as vulnerable, 46 as rare, two as reliant on the western division in a national context, and two as secure but having disjunct occurrences in the division. Two broad habitat types, riverine areas and Triodia grassland, are particularly important. Further taxonomic work on eight species is needed to determine the distribution and status of redefined taxa and to clarify the genetic relationships of disjunct populations.

Notes: As indicated in the abstract the conservation status of the herpetofauna in the western Division is determined and analysed. Threats: Most obvious threat - clearing of mallee; less obvious are threats posed by habitat modification: Fire - most studies focussed on mallee and indicate that the diversity and abundance of some species are influenced by burning frequency; seasonal conditions & amount of fuel available during the combustion stage of a fire can interact critically on a species biology. Fire affects shelter, predation, prey availability, foraging and perching sites and generally mid or late post-fire successional stages with structural diversity in the shrub layer, leaf litter and fallen timber have been re-established. Recolonisation is also more rapid from a mosaic burn which provides refugia. Survey work in the north-west of NSW indicates
an overall decrease in species diversity following fire. Effects of stock grazing on herpetofauna largely unknown but the importance of shrub structure and leaf litter piles for skinks in shrubland in western NSW has been clearly demonstrated. Other impacts of grazing could include soil compaction and erosion, affecting species living in cracks or burrows or which forage in the surface soil and trampling of leaf and debris piles around trees and shrubs.


Abstract:
Notes: Provides maps of bioregions where changed fire regimes has been identified as a threatening process for threatened ecosystems and bioregions where changed fire regimes has been identified as a threatening process for threatened species


Abstract:
Notes: Proceedings of a conference held in Brisbane in 1985. Papers cover: Descriptions of Mulga and the mulga ecosystem; landuse and its implications for the mulga ecosystem; management for sustainability of the ecosystem; nature conservation in the mulga zone; and land administration


Notes: The fire management strategy described by the papers in this book aims to maintain the land units by ensuring that a spectrum of post fire vegetation stages is always present in the park and that any wildfire event will not burn all the park. The conventional approach to fire management uses fire breaks which will create straight lines along artificial boundaries. Fire breaks remove vegetation in strips either by graders which destroy the soil surface or by line-burning (labour intensive) - these methods may be useful for protecting life and property but inconsistent with the management of natural ecosystems. The proposed strategy deliberately burns small patches, using natural features and diurnal weather conditions to retain control of the burn. Once begun, management intervention becomes a part of the natural land-plant-weather-fire system. It promotes diversity.


Notes: Describes changes on property in 15 years. Has tried a variety of ways of controlling
scrub and found that wherever the soil has been disturbed there was very little success (14%) while using a scrub cutter was much more successful (75%). Disturbing the ground fosters the growth of woody weeds and all the old disused crop paddocks in the western division support established stands of shrubs, mainly hopbush. Also after every major drought woody weeds are the first plants to grow on areas of drift ground. Also believes rabbits kept the shrubs at bay.


Abstract: Reptile and terrestrial beetle populations were sampled within adjoining mallee communities of similar botanical composition, but differing in fire history and vegetation structure. Studies were aimed at determining whether there were any major differences between faunal communities in sites with different fire histories. While the number of beetle species captured was significantly higher in the two most recently burnt sites, overall abundance of beetles did not differ significantly between various fire histories. Captures of Carenum interiove were highest in a site burnt seven years prior to the study whereas captures of Tvichocarenum sp. were most common in the two most recently burnt areas. The number of reptile species captured did not differ significantly between sites but the relative abundance of nocturnal and diurnal reptiles was found to be significantly related to time since last fire. The number of geckos captured at the oldest fire site (burnt 18 years earlier) were significantly fewer than at the more recently burnt sites whereas captures of diurnal lizards did not differ. These patterns of reptile abundance are consistent with those found in other fire studies undertaken in similar habitats. This preliminary study confirms that both reptiles and beetles may be usefully incorporated in future management systems designed to monitor biological diversity in mallee ecosystems.


Abstract: A number of burning procedures were investigated over three seasons for their potential to kill individual sifton bushes (Cassinia arcuata). The methods compared were an unburnt control, a foliage-only bum and a factorial arrangement of two basal burning energies (20 and 56 kW) for three durations (3, 6 and 9 seconds). Burning shrub bases generally killed more shrubs than burning the foliage. This was attributed to thin bark and lack of below-ground shoot meristems. Within the range of intensities used (195 kW/m and 545
kW/m), duration of the basal bum had more influence than intensity in killing shrubs. Small shrubs (<800 mm) were generally more easily killed by burning. Shrubs were more susceptible to all burning treatments in spring 1990. Subsequent dry conditions were suggested as a probable reason for this. The results and observations following fires in stands of sifton bush indicate that it is a seed regenerator following fire. Unless some means of controlling seedlings is available, caution should be exercised when using fire to control this species.


**Abstract:** Ecological and historical data are combined in assessing the influence of cultural broadcast burning in the inland Pacific Northwest from the distant past into recent history. Twenty-four references to broadcast burning by native peoples were found in the journals of early explorers and settlers. Broadcast burning was apparently an ancient native tradition, derived from the earliest hunting cultures to enter the region. With the influx of European culture, misapprehension about fire among whites disrupted the original influence of native cultural burning. Early irresponsible burning became associated with the deterioration of natural resources, and efforts to prevent or suppress all fires were incorporated in developing conservation policies. The reduction of burning, combined with markedly intensified grazing by European livestock, distorted the basic character of existing ecosystems and altered native plant communities. Early photographs of rangelands in east-central Oregon were gathered; their dates range from 1880 to the early 1930s. Photo-sites were re-photographed in 1976. Photoset comparisons show expansions of western juniper populations into adjacent rangeland ecosystems.

**Notes:** Fire is especially harmful to shrubs in drought conditions. In the Pacific Northwest fire and grazing are linked in the competitive relationship between woody and herbaceous species. In general these species act reciprocally in the flux of sagebrush and bunchgrass populations in grassland associations - fire tends to favour the perennial grasses over shrubs and excessive grazing tends to deplete herbaceous populations allowing woody species to increase. But the interactions are very complex - this is discussed. The presence or absence of large herbivores has contributed formatively to the nature of range vegetation all over the world.

**Concluding summary:** Cultural broadcast burning probably began with the entry of hunting cultures in the Pleistocene and persisted into historical times after the arrival of European people; Use of fire by stockmen inconsistent and became abusive to native ecosystems; displacement of native herbivores (bison etc) with domestic stock significantly altered grazing behaviours and intensities - natural ecosystems disrupted and native foliage depleted; uncontrolled fires became associated with deterioration of forest and range resources; broad policy of fire exclusion developed and fire removed from the natural ecosystem; western juniper populations have expanded markedly over 75 years. The native character of natural ecosystems have been significantly affected by the cultural history of the region. The agencies of fire and grazing as they acted in the primeval environment have been more or less inverted
in some areas leading to an expansion of shrub populations at the expense of grasses and forbs.


**Abstract:**
**Notes:** Clearing and felling of Mulga in Eastern Australia: where mulga scrub has regenerated well after clearing the proportion of unpalatable shrubs such as *Eremophila* and *Dodonaea* is often vastly increased. In SW Qld mulga has generally regenerated well after clearing although woody weeds can form a significant understory in some areas where sheep are run. Regeneration of mulga within groves in Central Australia is also fairly reliable because the incidence of fire is low and only cattle graze the area.

**Simpson I. (1992) Rangeland Management in Western New South Wales. NSW Agriculture.**

**Notes:** Enterprises, Climate (map of change from summer dominant to winter dominant rainfall), Soils & their management, vegetation, Managing the Vegetation (Map of woody weed infestations; management burning suggested as the most economical and ecologically desirable control method over large areas, long term planning necessary), Property & grazing management, Sheep production and management, Beef cattle production and management, Goat production and management, Damage to livestock caused by seeds, Poisoning caused by plants, Rangeland pests

**Sinclair Knight Mertz (SKM). (1998) Overview of Research on Grazing Management and Land Use in the Western Division. Background Paper No: 1.**

**Notes:** Aim of this paper is to consider all factors impinging on Total Grazing Pressure in the western Division and to show how these factors can be integrated on a paddock, property and regional scale to give best management practice.


**Notes:** Results of a fauna survey of the Northern Floodplain Region of the Western Division. Includes the vegetation and fauna of the riverine woodlands, Barwon woodlands, Wombeira woodlands, Belah woodlands, Brigalow woodlands, Gunderbooka woodlands, Lightning Ridge woodlands, Ledknapper Spinifex, northern open plains, shrublands and grasslands.

Abstract: An assessment was made of historical change in the native bird fauna of the Western Division of New South Wales. Change has been more extensive than generally recognised. It was concluded that 103 native bird species and sub-species (35% of the total) have decreased since European settlement and 83 (29%) have increased while 105 (36%) have shown no consistent overall trend. The most pronounced changes have involved 20 decreasers and eight increasers, including six species that are now presumed extinct in the Division, five species that now only occur as rare vagrants and four recent colonists. Overall, more birds have decreased in the semi-arid zone of the division than in the arid zone, and more in mallee scrub and eucalypt woodland than in other vegetation types, due largely to the pattern of vegetation clearing in the Division. Other factors (overgrazing, introduced predators and for some species, reduced prey populations) are implicated in the major declines and these have been more evenly distributed in relation to climatic zones and vegetation types. Marked features of the decreasers are an over-representation of Australian endemics, residents, woodland and scrub birds, tree and shrub nesters, and birds with a clutch size of only one or two. Specific features of the major decreasers are an over-representation of non-passerines, birds restricted to a major vegetation type, ground foragers and ground nesters. The increasers include many wetland birds that have benefited from the creation of additional permanent wetlands in the Division. Among the terrestrial increasers, there is an over-representation of birds of open vegetation, ground foragers and regular drinkers. Factors responsible for past avifaunal change continue to operate, and new threats have arisen. Effective conservation of the bird fauna will require not only further reserves, but also active management both on and off reserves. Pre-requisites for success are a better understanding of the processes of change and a greater co-operation among land managers.

Notes: Historical change has been less obvious and attracted less attention the mammals. Foxes invaded the Western Division in the 1980s but feral cats were present much earlier - possibly before the first explorers. Some change in status indicated for almost 2/3 of the native birds of the western division with decreasers outnumbering increasers 5 to 4. 20 species have undergone particularly pronounced declines and six of these (2%) are now presumed extinct in the region. 38% of mammals have become extinct. Magpie Goose and Flock Bronzewing - previously described as extremely numerous in lower Murrumbidgee and lower Lachlan, Black Bitterns in considerable numbers at Depot Creek well inland of current distribution. Sandhills on Darling River below Menindee - Banksias supported populations of nectarivorous honeyeaters - Regents, Wattlebirds, Tawny Crowned honeyeaters. Original vegetation long since been dramatically altered. Conservation of the Mallee fowl in NSW. Threats - Priddel

**Abstract:** We explored the key issues that are most likely to influence any set of guiding principles for developing biodiversity monitoring programmes in Australia's rangelands. We defined the Australian rangelands and came up with an overview of their climate extremes, land-use pressures and biodiversity loss, and then focussed on issues underpinning the design phase of any monitoring programme. Using Noss's 1990 framework of compositional, structural and functional attributes of biodiversity and its new revisions by others, we showed how the elusive, abstract concept of biodiversity can be used to identify many measurable attributes that can form a minimum and necessary set of indicators for any biodiversity monitoring task. We then described the steps in the monitoring process, with a particular focus on the reasons for monitoring biodiversity as they strongly influence the selection of indicators. We concluded by compiling a table of key issues as background information for developing guiding principles (Table 4). The list is by no means an exhaustive list for the design phase but it does indicate that considerable attention needs to be given to this phase when developing monitoring programmes. We have intentionally not addressed the equally important issues associated with the planning and delivery phases of developing a monitoring programme, as Wallace *et al.* and Watson and Novelty cover these in their papers in the present issue of Austral Ecology.

**Notes:** Paper introduces a volume of Austral Ecology that focuses on the need for monitoring of biodiversity. Australia's rangelands: 70%, 6 million ha; climate extremely variable and unpredictable. Provides map of moisture zones (arid, semi-arid, dry humid, moist) with an overlay of the defined rangelands. Substantial rainfall events produce a significant vegetation response that resembles a series of pulse and decay functions of growth and vegetation senescence and these responses might or might not form trends. Fluctuating climate also affects the frequency, intensity and extent of fire in the rangelands through variable fuel loads. Condition: 13% degraded, 16% affected by sheet and rill erosion, 17% as being affected by woody weeds, 25% of landcover as significantly disturbed (1996 report) - not evenly distributed across the rangelands. Monitoring rangeland biodiversity important for biodiversity conservation and landuse sustainability.


**Notes:** Contains broad description and map of the results of the survey covering: sheet and rill erosion, gully erosion, mass movement, wind erosion, dryland salinity, irrigation salinity, scalding, induced soil acidity, soil structure decline, woody shrub infestation, land use, tree regrowth occurrence of perennial bush. **Woody shrub infestation** - Because woody shrubs are unpalatable, livestock concentrate in and overgraze adjoining unaffected areas which become more susceptible to degradation. Other
land management issues include mustering difficulties, reduced grazing capacities, less drought resistant pastures, greater stock losses during periods of flystrike, lower lambing rates, lower land values. Species included are *Eremophila sturtii* (turpentine), *E. mitchellii* (budda), *Dodonaea viscosa viscosa* (narrow leafed hopbush), *D. v. angustissima* (broad leafed hopbush), *Senna eremophila* (punty bush), *Senna artemisioides* (silver cassia). Almost 70% of the western division, is affected by woody shrub infestation, minor areas in the central division, severe infestations occur on the sandplains of the Bourke-Wanaaring district and on the dunefields west of Tibooburra. Moderate infestations occur in the area covered by Enngonia, the Bulloo Overflow, White Cliffs, Wilcannia and Nymagee. Also the Broken Hill-Wentworth and Ivanhoe-Hillston areas. Usually found on sandplains and dunefields.

Tree regrowth: Defined as the emergence of juvenile saplings or other young growth underneath or near to a mature tree. Not shrub regrowth. Many kinds of degradation are either caused or aggravated by tree removal or destruction or lack of tree regrowth. In the western division - 68.7% with no regrowth (including shrub infested areas).


Abstract: The pattern of substrate, climatic, vegetation and fire features in the Tanami Desert were considered in relation to the ecological model for arid Australia proposed by Stafford Smith and Morton. The nature and accuracy of spatial data used to describe and quantify the pattern of the landscape features were also examined. Components of the ecological model were accurately reflected in the study area. For example, substrates identified as the most productive amounted to less than 8% of the region, and there was substantial spatial and interannual variation in rainfall. However, a strong climatic gradient was also evident in the study area, a feature not accommodated for in the model proposed by Stafford Smith and Morton. Vegetative ground and shrub cover decreased from north to south and was strongly associated with increasing aridity and lower maximum and minimum temperatures. Spinifex (*Triodia* spp.) cover showed a curvilinear response. The spatial data for both substrate and fire history were reasonably accurate (around 90%) when compared with ground-truthed data, and is considered suitable to reflect ecological pattern and process in the Tanami Desert. Both the adequacy of the ecological model and accuracy of spatial data are important issues to consider before the development of statistical modelling for prediction of species distribution.

Notes: Big fires in the Tanami Desert tended to follow big rains the frequency of fire was still greater in the north. The pattern of fire in the Tanami indicates an interplay of rainfall gradient, episodic rainfall events and substrate in plant production. There are also large areas that remain unburnt e.g. low proportion of fluvial surfaces burnt compared with sandplain - supports the contention that saline, calcareous and drainage lines tend to act as fire breaks.

**Abstract:** This study uses analysis of faecal pellets to assess the diet of the bilby (*Macrotis lagotis*) in an area spanning over 230 000 km² in the Tanami Desert, Northern Territory. More specifically, we examine the link between diet composition, bilby prevalence and the landscape variables of fire, rainfall and substrate. Seed promoted by fire, particularly of *Yakirra australiense*, was found to be one of the most important components of the diet and constituted ~36% of the relative abundance of identifiable food particles. Bulb from *Cyperus bulbosus* was also an important component of the diet (18.5% relative abundance). Invertebrates accounted for 39% of the identifiable food particles, and termites and beetles were the most common types. Bulb and seed formed a greater component of the diet in the central part of the study area where bilbies were more prevalent. Conversely, invertebrates were more dominant in the bilby diet on the northern and southern periphery of the Tanami Desert. Substrate type and antecedent rainfall associated significantly with the amount of seed from fire-promoted plants and total plant contained in the diet. Time since fire was an additional factor associated with the abundance of dietary fire-promoted seed. This suggests that the spatial and temporal variability of these landscape variables play an important role in controlling the availability of seed and bulb resources used by the bilby, and thus affect bilby prevalence. The results support the proposition that seed and bulb plant foods are exploited opportunistically and invertebrates, especially termites, are relied upon when plant food resources are scarce. Furthermore, the findings indicate that fire management could be used as a means to increase the favourability of habitat for the bilby in parts of its current range.

**Notes:** Proximity to recently burnt habitat is significantly associated with bilby occurrence. Fire management presents an opportunity to improve habitat suitability and bilby status.


**Abstract:** Fluctuations in the composition and abundance of a small-mammal assemblage were studied in a hummock grassland dominated by *Plectrachne schinzii* at Watarrka National Park from 1988 to 1993. During this period an experiment was conducted to examine the short-term effects of fire on the rodents. We caught three species of rodent (*Pseudomys hermannsburgensis*, *Notomys alexis* and *Mus domesticus*). All species reached their greatest density in spring 1989 during an exceptionally wet period that extended from mid-1988 to 1990. *P. hermannsburgensis* was the most abundant species and showed a 10-fold fluctuation in numbers over the sample period; *N. alexis* was the next most abundant species and showed a 5-fold increase but the population took longer to decline. *M. domesticus* was recorded only during the period of high rainfall. The number of *M. domesticus* was significantly less on the burnt plots than on the unburnt plots. Neither *P. hermannsburgensis* nor *N. alexis*
showed significant differences between burnt and unburnt plots. This study illustrates the impact of rainfall events on the composition and density of small-mammal populations in spinifex grasslands in central Australia. Our results lead to the prediction that rodent populations will achieve densities in the order of 10 individuals ha⁻¹ or more in regions that experience three consecutive 6-month periods each with rainfall at 150% of the long-term average. This sequence apparently needs to follow a dry period where rainfall is no more than 85% of the long-term annual average for two consecutive 12-month periods.


Notes: The primary aim of the project: To develop the use of plant specific biocontrol agents to control native woody weeds. Results/Conclusions: There are biological control agents that attack specific woody weeds but do not damage other plants - this includes Psyllids, mites, mealy bugs and scale insects; there are agents that are not controlled by parasites and predators; dispersal of these invertebrate agents can occur within normal property management practices; these biological control agents will kill woody weeds without other control techniques. Further research is recommended and outlined.


Abstract: There have been few attempts to describe the key ecological relationships which may be controlling the biotic structure of the Australian arid zone. We develop a series of 'propositions' which state explicit models about the functioning of inland Australia, based on its special physical environment. These special features - an extremely unpredictable but only moderately arid climate, ancient and infertile soils, and a high degree of soil differentiation - are not unique to Australia, but are combined there over a majority of the arid zone, which makes up 70% of the continent. These features define a specific range of establishment and persistence opportunities for plants, with fertile or reliable sites scattered like islands in a sea of exceptionally infertile and unreliable conditions. However, unpredictable heavier rains result in a high diversity and persistence of perennial plants, which, in turn support relatively stable populations of suitably adapted consumers. Mammalian herbivores are focussed on small parts of the landscape whereas detritivory and ectothermic predation predominate most areas to an extent not seen in other well studied deserts of the world.

Notes: In Australian deserts lizards and invertebrates are extraordinarily diverse. Spatial heterogeneity has also been a confusing factor in a superficially uniform landscape. There are subtle patterns in soil and vegetation.
Special characteristics of the physical environment:

*Rainfall unpredictability* - rainfall is the principal physical and biological driving force in the arid zone. It is very unpredictable in space and time.

*Big rains structure the environment* - These rains create major patterns in both the physical & biotic environment and sustain unexpectedly high levels of biomass.

*An ancient well sorted landscape* - the high degree of local soil differentiation has ecological significance because nutrients and surface water tend to move together.

*Highly patterned plant production*: Extremes of soil moisture play a crucial role in determining the diversity of plant life histories on different substrates; germination and establishment are determined by periods of high soil moisture, whereas persistence is determined by periods of moisture deficiency. Soil moisture also interacts with fertility, fire and plant competition.

*Fertility controls digestibility*: Low fertility soils produce plants difficult for herbivores to digest. Fertility is related to water supply so predictable patterns of production and digestibility occur across the landscape.

*The importance of fire*: This is an important driving force because of high perennial biomasses, slow rates of decomposition and plentiful carbohydrate-based tissue. It may be infrequent but fire plays a crucial role in maintaining plant species diversity at a site by removing adult plants and re-cycling nutrients.

*Food rather than water governs animal life*: Critical for the persistence and reproduction of arid zone animals - water rarely independently limiting.

*Herbivores are constrained by inadequate production*: Herbivores tend towards opportunistic presence of ephemeral species or more persistent specialised use of perennial plants.

*Infertility favours termites*: Areas of infertile soils support large amounts of plant biomass that are too poor for persistent use by herbivores to use - a large proportion of the production goes into the detritus pathway dominated by termites.

*Continuous production supports persistent consumers*: Areas characterised by continuous production are dominated by primary consumers exhibiting persistent presence.

*Social insects, uncertainty and infertility*: Ants and termites are prominent in the infertile environments - the colonies act as storage organs which can buffer the pulses of production and they can forage more widely than individual insects for sparse and intermittent resources.

*Patterns of higher order consumers*: The assemblages of higher order consumers is governed by the mixture of primary consumers so the food web reflects a pattern of water and nutrient availability. The homeotherms (birds and mammals) largely excluded from poorer landscapes which are dominated by reptiles and invertebrate predators.

*Consumer stability is surprisingly high*: The environment is not simply one of boom and bust due to various forms of buffering.

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**Stafford Smith D. M. & Pickup G. (1990) Pattern and production in arid lands. In:**


**Abstract:** Attempts to detect biological change in Australia's ancient arid landscapes are
often confounded by complex spatial patterns in soils, and physical processes such as runoff. These patterns are exploited and exaggerated by plants and animals, many of which survive because of local concentrations of resources. They are also crucial to land managers, who must deal with spatial heterogeneity within, rather than between, their management units such as paddocks and parks.

We show how a few simple assumptions about the effects of erosion and grazing in an hypothetical paddock can result in complex ecological patterns involving changes in variances as well as means across the landscape. The apparent noise that would be obtained by sampling these patterns at a few individual points can thus be rendered meaningful in terms of the spatial relationships between points. We discuss the implications of this for data collection and resource management.

Notes: Australia’s arid landscapes are characterised by high degrees of spatial and temporal variability e.g. mosaic of nutrient rich and poor patches. Our arid lands are spatially diverse and management is on such a scale that the heterogeneity is usually reflected within rather than between management units such as paddocks or parks. In addition our ecological thinking has been constrained by work from other parts of the world where spatial patterns can be more safely ignored.


Notes: Discusses risk management and the law. Definition from the Aust standard on risk Management AS/NZS 4360 - ‘The chance of something happening which will have an impact on objectives’. Risk is conceptualised as having both positive and negative consequences in the context of objectives - it links risks with peoples aspirations and values.

If the multidisciplinary process will address many of the identified gaps it will need to:
1. ensure social, economic and scientific inputs that are credible
2. devise risk management that is socially, economically and scientifically robust
3. come up with procedures, processes and outcomes that have wide societal legitimacy

Abstract: Management of the dynamics of woody vegetation in Australia’s tropical savannas is a vexing issue for both pastoralists and conservation biologists. In savanna regions around the world, increasing density of woody vegetation contributes to declines in pastoral productivity, but its effects on native fauna are largely unknown. In this paper we examine the avifauna in savanna woodlands of varying structure in the Desert Uplands bioregion, Queensland. Vegetation cover maps derived from aerial photographs were used to choose 60 sites, across 4 cattle stations. We sampled sites mapped at 30–45% and 45–60% foliage cover, and areas which previously had these levels of cover but had been mechanically modified, both by broad scale clearing and selective thinning. Between May and June 2004, we measured a range of habitat variables and sampled the birds at each site. Bird species composition varied significantly between treatments. Bird richness and frequency was greatest in intact vegetation. Thirteen species of birds were most frequently encountered in sites with 30–45% canopy cover, compared with 10 species in the 45–60% cover sites, 4 species in the thinned sites and 7 in the cleared sites. Our results suggest that increasing density of woody vegetation in savanna woodland may be to the advantage of some savanna bird species. Mechanical modification to reduce woody vegetation appears to also benefit some common, widespread species, but has a generally negative overall effect on bird species richness.

Notes: Bird frequency and richness indicated a relationship between bird assemblage and vegetation structure and that intact vegetation is preferable to many bird species, possessing a higher overall bird species richness while cleared sites had the lowest richness and thinned sites were intermediate. Species occurring frequently in cleared sites (eg zebra finch) and grazing increasers (peaceful dove) had a clear negative relationship with increasing cattle tracks (measure of grazing intensity). The maintenance of savanna biodiversity depends on the retention of areas that vary in resource availability, floristic composition and stage of succession after fire. This study also indicated that variation in vegetation structure also plays a similar role.


Abstract: Despite the widespread distribution of Callitris glaucophylla J. Thompson & L.
Johnson (white cypress pine) over large areas of eastern Australia, little is known about its impact on the diversity and cover of understorey plants. We examined *C. glaucophylla* woodlands to see whether stand density and land management influenced the cover and composition of the understorey vegetation. The cover and diversity of understorey plants and the cover of trees increased, and the composition of the understorey community changed with increases in average annual rainfall. There were no clear relationships, however between tree cover or density, and the cover or diversity of understorey plants. Sites that had not been logged contained significantly greater proportions of native and perennial vascular plants, and sites with extant eucalypts had a significantly higher proportion of shrubs than those without eucalypts. We attributed these differences to past forestry disturbance regimes which are correlated with the presence of mature eucalypts. Our results do not support the proposition that dense stands of *C. glaucophylla* suppress understorey vegetation.

**Notes:** Sites were located from Eugowra to Pooncarie and included sites on the Cobar Peneplain and the Riverina region. Despite suggestions that the dense cover of trees limits the growth of understorey plants study was unable to find a clear relationship between canopy cover or wood density and vascular plant cover or composition. Unable to accept the initial hypothesis of differences in understorey vascular plant cover and wood density in relation to tree cover. This lack of a relationship was consistent even when we accounted for differences in rainfall.

The lack of a clearly defined relationship between the understorey and overstorey components is probably related to differences in the intensity of grazing which influences biomass, cover and density of the understorey plants at a range of spatial scales. The reasons for the poor relationships between tree cover and understorey are more obscure. Complex interactions between grazing, rainfall, plant physiology and previous management are involved, and are known to influence the cover and composition of *C. glaucophylla* understorey. The multivariate analyses confirmed that as expected rainfall was largely driving the distribution of species across the east-west gradient, although soil texture and carbon were also implicated. Study showed that sites that had not been logged contained a greater proportion of perennials and natives.

Sites where mature eucalypts were present had significantly greater cover and density of shrubs than sites without eucalypts. Floristically rich vegetation is not incompatible with a dense cover of cypress.


**Abstract:** A rational analytical approach to the restoration of degraded rangelands is proposed in which degradation is described in terms of loss or diminution of plant habitat favourability. The approach recognizes that fertile patches or zones are maintained by the action and interaction of abiotic and biotic transfer processes. The identity and character of these processes can be deduced from data derived from integrated vegetation and landscape surveys. Ecosystem function and dysfunction can be identified and geographically referenced.
by this procedure. Finally, restoration practices are aimed at reconstituting the landscape processes 'normal' to the ecosystem in question.


**Abstract:** We studied three sites in central Australia with a range of use by cattle to see whether the soil had lost its capacity to support the vegetation assemblages present prior to grazing, and also to investigate whether degradation processes might reverse if stocking policy is changed. On the most heavily utilised sites, the soils were unstable and infertile and the landscape had lost nearly all its capacity to trap and use scarce resources effectively. The moderately utilised site had lost some of the soil/landscape productive potential, but could improve given good seasons and light stocking. A site which had been destocked for 10 years had stable, fertile soils and a number of means in the landscape of capturing and utilising scarce resources such as water, top soil and organic matter.

**Notes:** Calcareous shrubby grasslands.


**Abstract:** Data on landform, micro-topography and hydrological features indicate that the grove-intergrove pattern in mulga NW of Louth NSW is maintained by differential erosion deposition processes similar to the dynamic erosion-transfer-sink geomorphic systems described for central Australia. This vegetation grove-intergrove patterning in eastern Australia is similar to, but differs in detail from, such patterns reported for arid and semi-arid Central and Western Australia. Groves or 'bands' of *A. aneura* in the centre and the west tend to occur on the downslope side of the 'risers' or on 'convex slope-breaks' where in the east such groves occur in distinct 'steps' of 'flats' in the landscape; there is a drop into the grove and a sharp 'erosion-scarp' below the grove. A prominent 'grass band', identified by cluster analysis as the *M. paradoxa* community type occurs immediately upslope of the *A. aneura* groves in the east. The *A. aneura* groves in the east are also 'fertile' patches as soils data demonstrate that groves have much higher levels of organic and exchangeable nutrients (and plant cover) than soils in the intergroves.

**Notes:** Biological activity in this environment is strongly influenced by the re-distribution of water and nutrients.

Abstract: A rehabilitation procedure designed to re-establish resource control processes in a degraded Acacia aneura woodland was successful in improving soil nitrogen and carbon content, exchange properties, and water infiltration rates. Soil respiration rates and soil fauna populations increased, and soil temperatures were moderated. The procedure comprised laying piles of branches in patches on the contour of bare, gently sloping landscapes, with the expectation that soil, water, and litter would accumulate in these branch piles, thus improving the soil habitat and its productive potential. The procedure was derived from landscape function analysis, indicating that surface water flow was the principal means of resource transfer in these landscapes. Under degradation such overland flow results in a loss of resources. This rehabilitation procedure reversed loss processes, resulting in gains in the productive potential of soils within patches. This procedure was successful despite grazing pressure being maintained throughout the experiment.

Notes: Degradation occurred within the first 20 years after settlement due to lack of appreciation of the innate unreliability of rainfall substantial decrease in fire frequency, increased grazers (feral, native and livestock) and slow movement of livestock from droughted properties. Degradation is continuing - loss of palatable perennial grasses, increased inedible native shrubs and ephemerals, soil erosion. Attempts to deal with perceived soil degradation were based on mechanical treatments aimed at increasing water infiltration but generally failed - favourable seasons didn't arrive to cause the response, soils slumped, the additional disturbance created further erosion and shrub regrowth was promoted, too expensive for marginal pastoral enterprises. Reseeding has also largely failed due to the soil type. Part of the problem with these methods has been that colonising plants would create a favourable soil microhabitat from highly eroded and unstable soils - solutions were too simplistic, water infiltration perceived as the only problem and little recognition of nutrient status and cycling. Water and soil nutrients are in short supply in arid and semi-arid lands and when upgraded these lands have a high diversity of perennial plants occurring in natural patches which capture and store water and nutrients then slowly release them over time to enhance survival of perennial plants.

Experimental trial of landscape rehabilitation carried out at Lake Mere Stn, western NSW by creating patches with mulga branches. On bare slopes, branch piles had a dramatic effect on soil deposition and erosion with clear gains of soil and water infiltration was increased markedly - 10x in 3 years. Significantly more rain can infiltrate into these landscape patches than into the surrounding landscape and less rainfall will run out of the landscape into creeks, rivers and lakes. Increased infiltration capacity probably involves organisms that process litter and create an open friable soil fabric - e.g. termites produce biopores. Soil nutrients in surface layers esp N and C and electrical conductivity increased in branch patches. This was especially apparent in grazed paddocks. Ants were much more numerous on the branch piles, probably preying on mites and spiders that had taken up residence in the trapped litter. Litter decomposition also higher. Destocking is not essential for this to be implemented.

**Abstract:** In the semi-arid woodland of eastern Australia, soil mounds are often associated with fallen mulga (*Acacia aneura*) trees. Measurements of the physical and chemical properties of the soils in these mounds compared with surrounding soils, together with differences in herbage growth responses, indicate that these mounds are fertile patches, with possible importance as habitats for soil fauna and as refugia for a range of organisms during drought. The mound soil material may accumulate by fluvial, aeolian or rain-splash deposition about the fallen log, however, some of the mound material was derived from termite feeding gallery structures. The surface feeding gallery material may be comprised of soil particles from within the mound or from tunnels and storage galleries below the mound, and probably depends on the termite species.

**Notes:** Landscapes have been described as mosaics of repetitive units or patches. In mulga there is the grove-intergrove patterning within which there are smaller patches or discrete units - 'mulga log mounds' which develop around dead or fallen mulga trees. Water infiltration is higher due to the soil fauna present and nutrient status higher due to presence of consumers and decomposers. The mounds were shown to be fertile patches with soils differing from surrounding soils by favouring herb growth, having significantly greater mineralisable nitrogen plus more organic carbon and total nitrogen. Water infiltrates more rapidly because the mounds are riddled with biotic micropores + higher sand content. Stability implies organic bonding mechanisms. Log mounds may be regarded as 'environmental resource patches' because they comprise a heterogeneous distribution of local physical and chemical resources accumulated by normal processes. These mounds appear to persist for many years. On the Lake Mere study site there were >100 mulga log mounds per ha representing a significant number of points of potential refugia within this system.


**Notes:** Desertification: originally coined to graphically represent the state of the Sahelian lands in the 1970s when major drought accompanied by big increases in human population apparently caused the desert margins to move into formerly more productive land. Most rangelands of the world have suffered from some degradation and the processes have not all been restricted to hot deserts of areas of high population density.

To maintain key soil processes a continual supply of fresh organic matter is required. As desertification proceeds the supply of organic matter topsoil organisms is greatly attenuated either because above ground material is harvested by large herbivores or simply because
production slows. Understanding what happens to the soil-dwelling organic matter processing organisms during this hiatus is central to understanding the effect of desertification at fine scales. Some *Acarina* mites have been shown to be adversely affected by heavy grazing pressure - a precursor to desertification. Mites occupy and rely on very small air-filled pores in the soil - their disappearance implies both a lack of organic matter and partial collapse of the soil structure. Soil compaction is often recorded as a consequence of desertification.


Abstract: The fire regime necessary to cause a significant topkill of bush in the arid savannas of south eastern Africa involves applying a surface head of fire with an intensity of approx 2500 k/sec/m at the end of winter when the grass sward is dry and dormant.

Notes: The arid savannas in southern Africa are one of the premier livestock producing areas of South Africa where livestock production is completely dependant on natural rangeland. The thornveld areas of the region are threatened by a serious bush encroachment problem. The seriousness of the problem lies in the fact that bush encroachment has significantly reduced the grazing capacity of the encroached rangeland. The ecological role of fire in controlling bush encroachment is to maintain bush at an available height and in acceptable state for browsing by livestock.


Abstract: The use of fire in the arid and semi-arid rangelands of southern and eastern Africa is generally limited to controlling the encroachment of undesirable plants into rangelands.

Notes: Should controlled burning be applied as a management tool and should wildfires be controlled? Suggests that fire should and can play an important role in controlling the encroachment of undesirable shrubs but is probably only practical in the semi-arid rangelands with rainfall 400-600mm. With less than 400mm, herbage too sparse to support fire.

Turner D., Ostendorf B. & Lewis M. (2008) An introduction to patterns of fire in arid and
Abstract: Fire is a crucial element in shaping our world, whether of natural or anthropogenic origin. These fires can have both positive and negative consequences and impacts on our natural environment, society and its economics, not to mention global climate.

Previous analyses of fire regimes in arid and semi-arid Australia have been of limited spatial or temporal extent. This lack of knowledge has hampered attempts at effective fire management. Satellite imagery allows the continuous detection, monitoring and mapping of fires. Active fires can be detected as fire hotspots, and burned areas mapped as patches from the change of surface reflectance properties in successive images. Data from NOAA’s advanced very high resolution radiometer (AVHRR) were used to assess the distribution, seasonality, frequency, number and extent of fire hotspots (FHS) and fire affected areas (FAA) across the entire arid and semi-arid country of Australia from 1998 to 2004.

Utilising both of these fire datasets is important, as they complement each other and provide a more robust analysis of fire patterns. Between 1998 and 2004 almost 27% of arid and semi-arid Australia burnt at least once. The main trends in fire distribution follow latitudinal rainfall gradients. Regression analysis also shows a strong relationship with the pattern of antecedent rainfall. The seasonality of fire events varies between climate zones in accordance with the varying distribution of precipitation and temperature, which influence fuel accumulation and curing.

For the first time we have a picture of fire patterns across the entire arid and semi-arid regions of the country. This includes several high fire years in certain areas following above-average rainfall. This analysis highlights similarities and differences between regions, giving policy makers and managers a basis from which to make more informed decisions in the present, and with which to compare future regimes.

**Notes:**

**Executive Summary:** This report documents the findings, conclusions and recommendations of an evaluation of the WEST 2000 Program. The evaluation relied on primary (including stakeholders) and secondary data sources.

**Background** - The ecological and socio-economic pressures in the western division have been recognised for many years. In the early 1990s, landholders in the western Division were faced with greater economic pressures - depressed commodity prices, poor seasons, high interest rates. WEST 2000 ($17.466 million) was developed in response. Conducted from June 1997 to June 2001.

**Outputs** - $0.88 million provided through 282 grants. Most projects for high cost woody weed control, with poor economic returns and low natural resource management benefits. 120,000
ha 'free' of woody weeds through these grants. Other outputs outlined.

**Series of conclusions presented:** Proportion of woody weeds cleared represents a very small proportion (~1%) of total area affected. Much of the woody weed investment is economically irrational for landholders and generates limited public benefits. These activities would generally not be carried out without WEST 2000 funding.

Grants for natural resource management - Further enhance the value of grants by requiring applicants to demonstrate an integrated approach to management using an array of technologies and including commitments to conservation and production outcomes; progressively withdraw funding from high cost woody weed control in densely infested areas by using a limit on the per ha cost e.g. $4; progressively withdraw funding from small scale woody weed control that has logistical rather then natural resource management benefits on the basis that this should be addressed as part of normal property management; evaluate the biodiversity benefits arising from past investments in woody weed control; continue the trend of encouraging involvement in preventative woody weed management using cost-effective technologies that will yield a higher public benefit, funding should be flexible.

4.14 Measure 14 Rabbit and woody weed strategy: Objective should be 'to engage widespread landholder involvement and participation in woody weed control programs.' The grant based projects for woody weed control were popular with landholders. Most popular methods were raking, blade ploughing and chemical usage with a lot of work targeted at areas where improved stock access required for mustering and handling of stock. Note - the use of intensive technologies has been shown to have a very low return on investment. Control using fire is much less popular. Despite the benefit cost ratio being much higher. Anecdotal evidence suggests germination high in 1998/1999 and very high in 2000. WEST 2000 allocated $180,000 to demonstrations and grants, $40,000 invested in 7 burning grants and developed information package 'Perennial Pasture Management Plan for Woody Weed Control' to encourage applicants to put woody weeds in the context of wider pasture management. People who undertook work felt it would impact positively on their viability but rated lower than investments in improved animal husbandry, water management and business planning.

The woody weed problem is the most contentious issue in the western division; they are believed to be the biggest problem but the science for their control is not believed to be conclusive; no widespread acceptance of control measures - most interest is on badly affected land despite Hassals showing the best returns come from control measures on mildly affected land; fire is the most cost effective and ecologically sound method but strong resistance to its use - not considered effective. Evidence of a lot of hearsay. BCA suggest that even with WEST 2000 funding woody weed control is not a good investment for landholder funds.

Abstract: Savanna ecosystems are characterized by the co-occurrence of trees and grasses. In this paper, we argue that the balance between trees and grasses is, to a large extent, determined by the indirect interactive effects of herbivory and fire. These effects are based on the positive feedback between fuel load (grass biomass) and fire intensity. An increase in the level of grazing leads to reduced fuel load, which makes fire less intense and, thus, less damaging to trees and, consequently, results in an increase in woody vegetation. The system then switches from a state with trees and grasses to a state with solely trees. Similarly, browsers may enhance the effect of fire on trees because they reduce woody biomass, thus indirectly stimulating grass growth. This consequent increase in fuel load results in more intense fire and increased decline of biomass. The system then switches from a state with solely trees to a state with trees and grasses. We maintain that the interaction between fire and herbivory provides a mechanistic explanation for observed discontinuous changes in woody and grass biomass. This is an alternative for the soil degradation mechanism, in which there is a positive feedback between the amount of grass biomass and the amount of water that infiltrates into the soil. The soil degradation mechanism predicts no discontinuous changes, such as bush encroachment, on sandy soils. Such changes, however, are frequently observed. Therefore, the interactive effects of fire and herbivory provide a more plausible explanation for the occurrence of discontinuous changes in savanna ecosystems.


Abstract: The Australian rangelands contain extensive and often dense populations of a wide variety of weed species. An array of techniques is available for effectively controlling many of these. To achieve long-term weed control, weeds should be targeted objectively and the dependence on the use of single treatments such as herbicides and machinery reduced, with a greater adoption of integrated methods. The combination of methods will differ if the primary objective within the rangelands is to restore and maintain biodiversity or to improve forage production for domestic and native animals. Revegetation of sites and exclusion of herbivores from weed treated areas is important in establishing species that will compete with invasive weeds. Due to rangelands being sparsely populated, the necessary equipment, skills and finances to use appropriate control options on extensive weed infestations are often lacking, with landholders requiring the assistance of local, state and federal authorities to assist in managing weeds.

Notes: Control methods include: prevention and early eradication, physical and mechanical control (blade ploughing, hand pulling, grubbing, slashing etc), fire, grazing management, chemical control, biological control, integrated weed management. Species being considered are introduced woody weeds e.g. Mesquite, rubber vine, prickly acacia, parkinsonia, chinee apple and some annuals and perennials. Most of the issues are the same as those for management of native woody species.

**Abstract:** No abstract - keynote address

**Notes:** 'Rangeland management is a complex optimisation process, and any optimisation process requires a clearly defined objective, a set of possible actions, and then a model which accurately predicts the combined consequences of any actions on the system.' Determinants of change: life-history characteristics of communities, community process (competition, facilitation, soil biotic changes), climate, fire regime, grazing & trampling pressure - working in concert. 'If there is a single paradigm that encompasses all rangeland dynamics then it would have to be that it is the interactive process between the five determinants that accounted for the observed patterns.' Equilibrium & non equilibrium paradigms would be true to different degrees at different times. Timing is critical.


**Abstract:** A study was made over a period of 12 years of the natural regeneration of vegetation along a corridor cleared for the construction of a natural gas pipeline in a semi-arid woodland in central-western New South Wales. Total cover, proportion of grasses, and species composition were assessed on the infilled trench and on areas from which topsoil had been bladed, as well as on adjacent undisturbed areas and areas burned by a wildfire. All areas were grazed continuously by sheep under normal station management, and by native animals. After four years of about average rainfall, total cover on disturbed areas had regained levels as high or higher than on adjacent areas, and was maintained thereafter. On many individual sites this period was as short as eighteen months. The proportion of grasses remained much lower on disturbed areas, except for some periods of annual grass dominance. Species composition remained very different between disturbed and undisturbed areas, the main difference being in perennial species. However, composition also varied markedly between years, according to rainfall seasonality and competition from previously established plants. Little difference was apparent between undisturbed areas and similar areas which had burned twelve months before the first measurements. Mechanical disturbance caused by trenching and blading had a much greater effect on vegetation than did fire, and the effects were still obvious after twelve years.

**Notes:** Study of regrowth after construction of the Moomba pipeline. Line built in 1974/5, very wet period 1975/6 + 1977 & 78. Dominance of grass species dependant on the month - even week - of the autumn rains. Burning caused a decrease in the number of species in all groups in first 2-3 years, thereafter little difference in undisturbed areas. Annuals initially dominant.
Study indicates critical effect of rainfall and possible effects of accumulated litter on species composition.


**Abstract:** A study was made over a period of 12 years of the natural regeneration of vegetation along a corridor cleared for the construction of a natural gas pipeline in a semi-arid woodland in central-western New South Wales. Total cover, proportion of grasses, and species composition were assessed on the infilled trench and areas from which topsoil had been bladed, as well as on adjacent undisturbed areas or areas burned by a wildfire. All areas were grazed continuously by sheep under normal station management. The effects of mechanical disturbance and of burning on individual species were measured in terms of species dominance and occurrence. Some insight was also gained in to the successional process on bared sites and in to the effects of the timing of seasonal rainfall on species composition. Of the 75 major species recorded, 15 were found to have greater occurrence on trenched sites, 46 decreased in occurrence and 14 showed no clear trend. Perennial grasses and small annual plants were the main decreasers, whilst Medicago spp., *Erodium crinitum*, *Hordeum leporinum* and certain 'weedy' annuals were the main increasers. Some of the early colonisers lasted only a few years or even less in any quantity, thereafter to be replaced by other increasers. Burning had little effect on the long-term occurrence of *Stipa variabilis*, *Wahlenbergia spp.*, *Helipterum spp.*, *Calotis cuneifolia* and some minor species. *Eragrostis lacunaria* appeared to decrease, while several annual plants were more common on burned areas.

**Notes:** The study found contrasting behaviour between perennial v's annual species and there were differing responses between the responses of annual species to the various levels of disturbance. Except in the short term following fire, burning has much less drastic effect on pasture cover and composition than mechanical disturbance. Grasses and groundcover species not shrubs in this study.


**Abstract:** (1) Semi-arid savannas, wherever they occur, have generally been overgrazed and encroached on by bush. A model is developed which accounts for the growth of woody vegetation and of grasses and analyses the competition between them for available soil water.

(2) The model is based on Walter's two layer hypothesis. Woody vegetation and grasses compete for water in the surface layers of the soil but woody vegetation has exclusive access to a source of water relatively deep underground. Where there is only a small biomass of grass the soil surface tends to become impermeable and, in these conditions, the model shows that
two different steady states may develop: with a lot of woody vegetation alone, or with a relatively large biomass of grass and rather little woody vegetation.

(3) The results are discussed in terms of the concept of resilience. The continued existence of both stable states under ranching conditions seems to depend on periodic heavy, or over-, grazing which allows for the maintenance of unpalatable or unstable grass species, which thus set a minimum to grass biomass - a minimum which cannot be reduced by herbivores.

(4) Comparison of the dynamics of various savanna and other natural systems leads to the conclusion that the resilience of the systems decreases as their stability (usually induced) increases.

Notes: A series of radical changes occurred in the semi-arid savannas beginning in the late 1800s when settlement by Europeans was at its peak. These changes are remarkably similar wherever semi-arid savanna is found. It was initiated by the introduction of domestic cattle or sheep or both and resulted in reduction of indigenous mammalian herbivores and predators.


Abstract: Global change is often equated to 'climate change' or 'global warming' but includes three components: (i) change of atmospheric composition; (ii) climate change; (iii) change in land use. Landuse change includes loss of land cover and the change in intensity of existing land use especially with respect to emissions or sequestration of greenhouse gasses. The primary change in atmospheric composition is increasing CO2 concentration. Climate change and its influence on the water balance include the hydrological characteristics of the soil and temperature as it influences the evaporative demand on the atmosphere. Secondary effects which may have a more significant effect than the direct effects. Modest changes in rainfall and temperature which significantly increase or decrease fire frequency may lead to large changes in vegetation structure and composition difficult to predict from changes in climate on its own. Other secondary effects include changes in the distribution and dynamics of pests and diseases, direct effects of climate on herbivores and changes in land use such as encroaching cultivation with increasing rainfall.

Notes: Discusses global change - direct and secondary effects.

Australian arid, semi-arid rangelands: often feature coexistence of grasses, trees & other woody species; vegetation is controlled by soil type and landscape factors; primary productivity is related to rainfall; fire is often an important factor in controlling vegetation composition and structure; grazing is the most extensive landuse.
Fire: with regard to global change fire is a driving force for change in the grass / tree ratio but the frequency, extent and intensity of fire are also affected by other drivers of global change, rainfall and land use practices. Fire regimes are affected by biomass accumulation rates, the dryness of the biomass and the grazing intensity. Heavily grazed areas seldom burn, burned areas are favoured by herbivores, periods of high rainfall lead to high vegetation biomass of lower quality (higher C:N ratio) and increased probability of fire, increased frequency and intensity of fire leads to a higher grass: tree ratio and therefore favours grazers, grazing tips the competition balance between trees and grass in favour of trees etc. Increasing summer rainfall (+increasing CO2) will most likely favour the C3 woody species over the C4 grasses. Alternatively if the rainfall comes in bursts with long intervening dry spells, fire frequency and intensity could well increase, favouring grasses. If grazing intensities are lowered grasses would be favoured.

Implications for feedbacks to atmosphere and for management strategies: Biomass burning in the humid savanna woodlands releases a large annual flux of greenhouse gases to the atmosphere but whether burning is a net emission of gases to the atmosphere with the significant gains in biomass in the quiescent periods between fires. Historically the emission of CO2 from the oxidation soil organic matter may have been important. In some areas overgrazing has resulted in the loss of as much as 2/3 of soil C in the upper layers (about 14t/ha C). Australia’s rangelands have contributed / are contributing to these emissions.


Abstract: Fire has been present during the evolution of poplar box communities and the flora is well adapted to fire. Broad fire regions are recognised on the basis of bioclimatic data and the effects of different fire regimes on plant species and communities are discussed in relation to these regions. Grazing combined with the variable rainfall makes the accurate prediction of vegetation changes resulting from fire difficult. Fire is currently episodically associated with over-average rainfall in most areas as the predominant fuel is grass. Minimum fuel quantities of 100 g m\(^{-2}\) in pastures where fuel is continuous and 150 g m\(^{-2}\) in pastures with discrete tussocks are required to carry a fire. Fire can drastically reduce shrub numbers, especially juvenile and seedling plants in the short term, but attitudes about using fire for shrub reduction vary from region to region according to the likelihood of growth or replacement pastures. Grazing control after burning to permit the recovery of the ground layer is difficult because of grazing by native herbivores. There is a need for further studies on fire behaviour and plant survivorship characteristics as affected by climate and native and domestic animal grazing.

Notes: Fires mostly caused by lightning >1 mill ha: NSW 1931 Louth, Menindee-Ivanhoe, Cobar-Tilpa; 1940 Roto-Hillston; 1957 Cobar-Roto-Hillston, Wanaaring-Hungerford, 1969 Roto-Hillston, 1974/5 Cobar-Hillston-Ivanhoe-Wilcannia; Qld 1918 Charleville-Barcaldine-Hughenden, 1941 St George-Dalby, 1950/1 Longreach-St George, 1968 Aramac. Grass major fuel, especially with Buffel grass - fuel load to carry a fire depends on fuel distribution and
moisture content. Fire frequency for western poplar box is about every 25 years. Rate of spread & intensity determined by wind speed, ambient temp, humidity, fuel quantity & moisture - effects discussed. Fire control practices - prevention, containment, reduction of rate of spread. Species & community responses to fire - ability to regenerate by resprouting, fire promoted seed germination, protected seed embryos, early reproductive maturity, heavy seed production, seed burial, seed longevity; differences between grasses incl *Heteropogon* & *Themeda* discussed, variability between species; Shrubs - highly variable survival rates, species readily killed, Cypress, *A. deani*, *Senna* sp, Hopbush, which produce prolific seeds, also age related. Fire promoted germination characteristic of species with hard seeds. Trees - Mulga, Cypress, Wilga, Kurrajong susceptible. Constraints on fire for management: land managers reluctant because of fear of control of management burn, unpredictability of responses to various strategies including botanical changes, economic benefits undetermined

**Walker P. J. (1978) The use of fire and stocking management to control woody scrub in the Cobar district, New South Wales. Soil Conservation Service.**

**Abstract:** Project proposal - Aims: The project involves financing of material and equipment-hiring costs for a study of scrub control by burning and stock management in the Cobar district of western New South Wales. The aim is to determine whether control of woody scrub by fire and subsequent stock management is effective in the areas which still produce sufficient ground fuel to carry fire.

**Notes:** Document discusses the accepted background of aboriginal burning controlling woody shrub growth, loss of productivity through loss of ground cover and increased soil erosion (watersheeting) under thickets - stock carrying capacity decreased by at least 50% since the 1950s. In normal years there is insufficient ground fuel to carry a fire. Most dense shrub growth was on the pediplain, less dense in surrounding landscape but increasing. Some plants killed by fire (30-80%), many resprouted from the base to 60cm after one year. Effects of follow up fire on regrowth to be investigated. Sites for trial: narrow-leaved hopbush on sandy soil, unburnt since 1934/36. Suggests soil type did not affect response of vegetation to 1974/5 fires. Autumn trials used because a previous burn at Nymagee produced a slow burn with a good hopbush kill and negligible seed germination. Regrowth to be sprayed with herbicide. Other questions to be answered include impact of grazing, soil nutrient changes etc.


**Notes:** Every fire is different and the success of a fire in killing scrub is due to the interaction of fire and seasonal characteristics e.g. fuel load, fuel moisture, distribution and arrangement of fuel, time of day, wind speed, relative humidity, air temp etc. Post fire seasonal conditions also affect recovery of pasture and shrub species. Fires of different intensity and rate of spread in
two different years produced kills of hopbush near Cobar of 48% when followed by a dry period and 10-25% when followed by a very wet period. The success of a fire depends greatly on a continuous fuel layer. The over-riding factor is fuel - one fire before Christmas with ground cover of 70% produced a good fire, six weeks later after rain, grazing by goats and kangaroos and drying winds the fuel cover was 50% and a fire that would kill scrub couldn't be achieved.

Many of the opponents of fire blame fire for the increase in populations and heating of the soil does appear to stimulate germination of some species especially Hopbush. However most germination of shrubs after fire coincides with wet periods and seedlings on burnt and unburnt sites are very similar. Fire can also affect pasture species with woollybutt & neverfail sustaining deaths and spear grass became dominant. Heavy stocking after a fire can cause more damage to pastures and soils than the fire.

Advice arising from this work:
1. Act while the shrubs are small and surrounded by grass. Dense stands of bushes will probably not burn
2. burn scrub infested areas whenever there is sufficient fuel and satisfactory (and safe) weather conditions, but ideally in autumn and spring
3. If necessary and possible conduct a follow up burn to control regrowth or bushes missed in the first fire
4. do not burn more than is necessary. Once shrubs in an area are cleaned up maintenance fores may be necessary only every, say, 10-15 years to control regrowth
5. Spell burned paddocks to allow pasture recovery and minimise soil erosion
6. Seek technical assistance in estimating the success of the burn, and determining the burning strategy and control measures required.
7. Enlist co-operation of neighbours in carrying out the burn and post-fire patrolling.


Abstract: Fire has reduced the shrub populations in most areas, despite a follow-up season favourable to growth. The species most susceptible to fire are white cypress pine and mulga, then punty bush and hopbush. The most resistant are turpentine, budda and pituri. The site effect is very variable, probably due to fire behaviour and fuel load. Fire does not appear to increase the germination of shrub seeds, with the exception of narrow-leaved hopbush, which appears to be stimulated by hot fires. Wet seasonal conditions appear to be a major factor in encouraging seed germination. Further information is required on the effect of repeated burning of shrubs, on post-fire management, on survival rates of seedling populations and on the effects of fire on certain pasture species.

Abstract: For the first time, a region-wide assessment of vegetation change across the southern shrublands of Western Australia is reported, using information from 965 shrubland sites of the Western Australian Rangeland Monitoring System (WARMS). The majority of sites were installed between December 1993 and November 1999, and were reassessed between July 1999 and November 2005, with an average interval of just over 5 years. Shrub and tree species density, canopy area and species richness remained the same or increased on the majority of sites. The results were similar when considered at a species level, with most species showing an increase in density, canopy area and the number of sites on which they were found. Recruitment of new individuals to the population was commonplace on virtually all sites and for virtually all species. High rates of recruitment, on many sites, were observed for long-lived species such as Acacia aneura Benth., A. papyrocarpa Benth., Eremophila forrestii F.Muell. and Maireana sedifolia (F.Muell.) Paul G.Wilson. Increases in density, i.e. where recruitment was higher than mortality, were observed for many shorter lived species which are known to decrease in response to excessive grazing (i.e. decreaser species) such as Ptilotus obovatus (Gaudich.) F.Muell., Atriplex vesicaria Benth., A. bunburyana F.Muell. and Maireana georgei (Diels) Paul G.Wilson. However, this result should be tempered by the understanding that acute degradation processes may still be occurring, especially within and surrounding drainage lines, which are away from where the WARMS sites are typically located. Grazing was implicated in decreased density on some sites, particularly those which had experienced below average seasonal conditions. On these sites, decreaser species were particularly affected.

Notes: The sites were from the southern Pilbara to the southern Nullarbor. The results were generally favourable suggesting that the negative impact of grazing was less than the positive impact of rainfall over the period of assessment. There is some evidence of adverse grazing impact at some sites where shrub density declined with the decline in decreaser species greater than for the increaser species. These sites were predominantly away from the drainage lines and other research has demonstrated that there is ongoing degradation along the drainage lines. If an ecological system is at equilibrium, a monitoring system such as WARMS should show equal proportions of increase and decrease over the long term. These results showed increase for most metrics but it is difficult to imagine the same rate of increase continuing through subsequent sampling cycles. Degradation within the arid shrublands of Western Australia has been well documented. The percentage of traverses assessed as in fair or poor condition in condition assessments was 50-68%. Anecdotal evidence suggests that shrub density has increased in many degraded areas but SA results demonstrate that shrub populations can recover from a degraded state.


Notes: Literature Review - semi-arid shrublands and woodlands not addressed.
Species responses to fire: resprouters - rhizomes, lignotubers, epicormic buds, active pre-fire
buds; obligate seeders - die and rely on regeneration from seed; seed storage & dispersal - on storage organs (cones etc), dormant soil seeds, create seeds rapidly after fire (Xanthorrhoea).

*Disturbance & succession* - fire is a disturbance followed by succession. Multiple states are possible within one community as well as multiple successional pathways. It is also being increasingly recognised that periodic disturbance is necessary to maintain diversity. Scale is important - equilibrium at a landscape scale may be the result of a distribution of states or patches in flux. This implies a role for people in ecosystem management and a focus on the conservation of processes rather than objects. *Threshold theory*: Fire fits into the non equilibrium paradigm and fire intervals should vary between a lower (to allow species vulnerable to frequent fire to reach reproductive maturity) and upper threshold (determined by species which would be vulnerable to a lack of fire).

Discusses fire in each of the Keith (2004) vegetation communities.

With climate change the incidence of days of extreme fire weather can be expected to increase. The challenge may be to keep natural fire frequency above lower thresholds. In the west if climate change brings drier conditions there may be reduced opportunities for wildfire of prescribes burning due to lack of grass fuels.


**Abstract:** Pasture Response: A study into the effect of fires on pasture response was carried out in the Cobar Shire. Five properties were selected, on which a total of 11 sites were located. Sites within each property were situated on the same land class on burnt and unburnt pastures. Step point measurements were recorded during the first field visit, after which the quadrat, groundcover estimation method was included due to the drought conditions present. Pastures regenerated better when rain fell shortly after the fire. Where rain did not fall soon after the fire regeneration was very slow. Effects of fire on pastures included an increase in the amount of bare ground on the burnt pastures. Areas burnt twice responded least of all the sites. The percentage of annual grasses and shrubs and trees in the pastures were significantly different between burnt and unburnt sites in some but not all comparisons.

Livestock management: Information from landholders in the Cobar Shire was obtained by questionnaire. The type of information sought included management practices during the pre- and post-fire period. Changes in the management of stock as a result of the fire were minimal. The landholders who had more than one holding of land were able to move their stock to that portion with the greatest available amount of available feed. Spelling of the burnt pasture had little effect on stock production when compared to stock which grazed the burnt pastures immediately after the fire. The major factors affecting both the pasture response and stock management decisions were the earliness of rain after the fire and the amount of rain received.

**Notes:** General review of the history of fire in the western division but mostly relied on records for other parts of Australia for Aboriginal use of fire and then quotes the 1901 Royal
Commission and other general sources as well as reports by Condon and Alchin on the 1957, 1964 and 1974-75 fires. Graziers keen to use fires to produce green pick also desirable for kangaroos.

Wildfire events: 1974-75 - fuel 2-2.5 tonnes/ha, dry times, electrical storms - 108 fires, 83 lightning strikes - 3.75 million ha burnt, 10 thousand km fences burnt, 49875 sheep/324 cattle lost; 1976-77 - dense growth of spear grass on previously burnt areas just under a million ha burnt; 1977-78 dry period - 116 thousand ha burnt; 1978-79 - 37,986 ha burnt; total 1974-1979 - 4,815,907 ha burnt, one third of this in the Cobar Shire.


**Abstract:** This compilation lists published research relevant to plant ecology on the Cobar Pediplain in western NSW. Most of the references are annotated. Reported but unpublished research has been presented as Divisional Working document 85 / 12. It pertains mostly to the red-brown earths of the western division of NSW that have been subject to shrub and tree invasion since settlement by Europeans, i.e. essentially the Cobar Pediplain. References are arranged alphabetically by author under the section headings below. A brief overview of research results and research in progress is provided at the beginning of each section. Papers published to March 1984 are included.

A. Natural Environment (climate, soil, erosion)
B. Land Management (clearing, other land treatment, plant introduction, fire, grazing)
C. Vegetation response (methods, plant ecology)
D. Author Index.


**Abstract:** The main task of rangeland restoration seems to be one of repair, or reassembly, of damaged landscapes and biota, but in fact, managers and scientists must assemble entirely new communities of plants and animals. The goals of particular restoration projects vary greatly, although they often contain the same set of potentially incompatible qualities, that is, the new community may be required to be self sustaining, stable, minimally disruptive to native biota, and yet produce a high yield of introduced animals. Ecological principals, theories, paradigms, and current ideas which may be usefully applied to restoration projects are discussed, as well as a general protocol to use in conducting restorations. Mychomzæ (special fungi on plant roots), natural seed banks in the soil, and colonizing abilities of plants are important considerations in the establishment of vegetation. Understanding the behaviour of species and species interactions is necessary (but not sufficient) in order to formulate ‘rules’ for constructing communities of plants and animals which would be self-sustaining, stable, minimally disruptive to native biota, and yet produce a
high yield of an introduced animal. Knowledge of succession, ecosystem processes, and the importance of spatial relationships of food and habitat for animals are all potentially applicable to restoration of rangelands. The application of ecological principles to restoration work has the advantages of efficiency of trials, generality of results, and an enhanced public image. In return, restoration work is the acid test of ecological science, that is, whether it provides the knowledge and understanding to recreate a new, functional, stable community. It also provides scientists with the opportunity to conduct large-scale and long-term tests of ecological theory, impossible in most other research projects.


**Abstract:**

**Notes:** Plant & soil carbon and nitrogen stocks increase with woody plant encroachment in north Texas rangelands

Above ground woody canopy cover and biomass (carbon) have increased in the past 70 years


**Abstract:** Regeneration of trees and shrubs was monitored over a five year period following the chaining of an area of *Casuarina pauper* (belah) woodland on Nanya Station in western NSW. Chaining occurred in July 1991, and following very high rainfall from August 1992 to January 1993 widespread regeneration of woody species occurred. There was no regeneration of Belah. Rosewood regenerated from root suckers, while *Myoporum platycarpum* and ten other perennial woody species regenerated from seed. Over a further three years of below average rainfall the more palatable species declined while the less palatable, in particular *Eremophila sturtii*, *Dodonaea viscosa*, *Senna artemisioides* and *Olearia pimeleoides* showed a significant increase over pre-chaining levels. These results are consistent with an assessment on the adjacent Ennisvale Station where an area was chained in 1970 prior to 3 years above average rainfall. These results suggest that the widespread clearing and thinning of belah woodlands which has occurred, particularly in the late 1960s may have contributed significantly to the increase in woody weeds in these areas. In addition the process has the potential to radically change the tree dominance over large areas of semi-arid woodland.

Abstract: We discuss what concepts or models should be used to organise research and management on rangelands. The traditional range succession model is associated with the management objective of achieving an equilibrium condition under an equilibrium grazing policy. In contrast the state-and-transition model would describe rangelands by means of catalogues of alternative states and catalogues of possible transitions between states. Transitions often require a combination of climatic circumstances and management action (e.g. fire, grazing, or removal of grazing) to bring them about. The catalogue of transitions would describe these combinations as fully possible. Circumstances which allow favourable transitions represent opportunities. Circumstances which threaten unfavourable transitions represent hazards. Under the state-and-transition model, range management would not see itself as establishing a permanent equilibrium. Rather it would see itself as engaged in a continuing game, the object of which is to seize opportunities and to evade hazards, so far as is possible. The emphasis would be on timing and flexibility rather than on establishing a fixed policy. Research under the state-and-transition model would aim to improve the catalogues. Frequencies of relevant climatic circumstances would be estimated. Hypotheses about transitions would be tested experimentally. Often such experiments would need to be planned so that they could be implemented at short notice, at an unknown future time when the relevant circumstances arise.

Notes: Range scientists have accumulated evidence where the assumptions of the range succession model do not hold. Vegetation changes in response to grazing have often been found not to be continuous, reversible or consistent. Vegetation has often not changed with the removal of grazing or changed as predicted. Mechanisms that produce complex ecosystem dynamics are:

Demographic inertia: the need for a rare event for plant establishment to occur but once it has occurred the resulting cohort can persist for a long time;

Grazing catastrophe: grazer intake and plant net growth and reproduction respond to plant abundance according to non-linear functions;

Priority in competition: Alternative stable states may result when the outcome of competition depends on the initial abundance of the competitors eg the adults of each species may have an advantage over seedlings of the other or interference such as shading might occur;

Fire positive feedback: Some vegetation components promote fire (eg grasses) and they are also promoted by fire. Woody plant populations may be competitively superior once established but fire sensitive in the seedling stage - these mechanisms produce alternate persisting states;

A vegetation change that triggers a persisting change in soil conditions.

State-and-transition model: uses management rather than theoretical criteria. Diagrammatically describes the various states and transitions for semi-arid shrubland/woodland in eastern Australia with a potential for increase of shrubs and also bladder saltbush. For the shrublands alternative persistent states arise because grass understorey is favoured by fire, while shrub understorey suppresses fuel. The critical management decisions arise after sufficient rain has fallen to produce fuels of ephemerals. Failure to burn at such a time risks large scale establishment of woody plants or misses the opportunity to control those present. Grazing consumes fuel so narrows the window of opportunity for burning.
Administration needs to: free managers to intervene positively. Where possible regulation should focus not on stocking rates but on changes in the actual state of the land or the vegetation; re-organise assistance schemes - drought loans, financial assistance for temporary destocking etc - so that managers can get help less often but in larger amounts - better to destock totally occasionally rather than by 10% continually; orient extension activities so managers are informed of a transition opportunity or a hazard is threatening and provide advice on possible actions.


Notes: Combining and applying different types of knowledge.
1. adopt an attitude of living with fire as an integral part of the landscape, treating many features of the landscape as assets, and focussing on particular objectives when using fire as a management tool
2. recognise that both fires and the biodiversity must vary across space (so that what is typical in one area may be extremely unusual in another) and recognise that fire as a management tool can be used at a very fine scale to produce a diversity of fire regimes across the landscape
4. understand that time-scales of post-European observations of fire regimes are very short indeed, relative to the responses of the biota, so there is a need to integrate many sources of information about fire patterns and ensure continuity of community knowledge (as well as information).
5. recognise the fundamental importance of monitoring over time, in order to make decisions about the timing of future management activities and to learn from past ones.

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Abstract: Studies of fire responses of plants and animals in Australian ecosystems have been accumulating rapidly in the past 20 years. Many patterns have been identified, ranging from local elimination of a species by a single fire to enhancement of population size or extent by fire, the latter almost amounting to complete dependence on fire for persistence. There is still insufficient information on fire response patterns to be able to identify particular fire responses and fire regimes - partly because of insufficient replication of fire studies on particular species, and partly because patterns have been shown to vary over space and time and are affected by variation in characteristics of the organism, the fire, the landscape and the climate. We conclude that except at a very coarse level, fire responses will be site specific,
making it almost impossible to predict the effects of a particular fire (or sequence of fires) on any species based on any number of studies of fire-response patterns at other sites and at other times. Instead of seeking general fire response patterns, we argue that the focus should be on using field experiments to understand how the life cycle processes that produce various patterns of fire response (mortality in fire, recolonisation, survival and establishment of individuals after fire, reproduction and population growth) and the factors that mediate them (e.g. habitat quality, nest sites, nutrient and food availability, predation) respond to different fire, landscape and climatic characteristics. This approach represents a major challenge for fire ecology and we present some case studies to illustrate how such field experiments may be conducted. An understanding of the way in which important processes respond to fire can then be combined with knowledge of an organism's lifecycle at the site and knowledge of the 'environmental template' (fire history, landscape characteristics and climate) to predict the effects of a particular fire or fire regime.

**Notes:** Responses of an organism, population or community will depend on the starting state of a community determined by the past history of the site (time since last fire) as well as fire characteristics (season, intensity, type, patchiness, post-fire climatic conditions). The range of strategies are discussed.


**Notes:** Discusses the co-operative programme instigated by the Quivira Coalition in New Mexico USA developed around the concept: can cattle, curlews, prescribed fire, ranchers, environmentalists and the US Forests service all get along together? A programme has been instituted and in 10 years benefits and failures have been identified. The concept needs refinement but not disbanding.


**Abstract:** Woody perennials have invaded semi-arid grasslands throughout the Southwestern United States. This invasion was coupled with decreased grass cover and increased runoff and soil erosion. Fire, which was a natural force that shaped and maintained the grasslands, is a management tool that may aid in restoring and maintaining grass cover. However, fire also poses the risk of increasing erosion and further soil degradation because protection afforded by vegetation is reduced immediately after the fire. Using a randomized block study design, this study measured vegetation cover, soil potentially mineralizable N, and erosion associated with the first application of prescribed fire on 2 semi-arid grasslands. The potential for adverse effects from these fires was great because the fires occurred at the beginning of a drought period. However, the effects of the burn were minor relative to the effects of the drought, which caused the greatest change. Grass cover on the burn plots was
nearly equal to grass cover on the controls 1 year after the fire. After 2 growing seasons, grass cover was equal on the control and burn plots. Potentially mineralizable soil N and sediment transport were similar on the control and burned plots during the 2 years following the fire. Thus, prescribed fire for reducing the cover of woody perennials may not increase the risk of site degradation over that caused by drought and weather fluctuations.

Notes: In the semi-arid grasslands of the SW US invasion by shrubs and trees occurred after periods of intensive grazing coupled with periods of drought from late 1800s to middle 1900s. Weather plays an important part in determining prescriptions for fires and effects from fires. Local variation in local weather patterns can play an overriding role in vegetation dynamics and erosion in these grasslands.


Abstract: The extent to which use of fire by Aboriginal peoples shaped the landscapes and biota of Australia is a contentious issue. Equally contentious is the proposition that attempts should be made to support and re-establish customary practice. Some dismiss Aboriginal practice as little more than culturally endorsed pyromania, and consequences for land, vegetation and wildlife management as incidental and unintended outcomes. We argue that this view of Aboriginal practice is at odds with available evidence regarding motivations for use of fire, and detailed and sophisticated descriptions of the consequences of poor fire management for the maintenance of important resources. We suggest that misunderstanding arises, at least in part, from the contrasting views that (i) objectives of Aboriginal land managers and the values they seek to extract and maintain in savanna landscapes are or should be similar to those of non-Indigenous land managers; or (ii) the notion that their goals are inherently and entirely incompatible with those of non-indigenous interests. We illustrate our argument with examples that include assessments of ecological consequences of 'prescribed' Aboriginal practice, statements from Aboriginal people regarding their objectives in applying those prescriptions, and the level of active organisation required for their effective implementation. Finally, we propose mechanisms for wider application of Aboriginal prescriptions in tropical landscapes to meet a range of land management objectives.


Abstract: Turpentine (Eremophila sturtii R.Br.) is a tenacious shrub that negatively affects rangeland, and is difficult to control by fire, herbicide or mechanical methods. When above-ground growth is removed, it sprouts vigorously from underground buds on the root system. Uprooting or grubbing is the removal of a shrub and its root crown with a U-shaped blade. Our hypothesis, that depth of uprooting and covering of all exposed roots with soil would
influence regrowth, was tested using 100 shrubs divided into five treatments of 20 shrubs each. Each of two depths, 10 and 25 cm, were divided into roots covered and roots exposed. The fifth treatment was uprooting at 25 cm with an extra-wide blade to increase lateral root cutting, and roots were covered. Uprooting depths could not be kept constant and varied from 9 to 33 cm. Plots were evaluated 30-months post-treatment. Roots covered with soil had significantly greater plant mortality ($P = 0.001$) compared with roots exposed at all depths, when grouped from either 9 to 33 cm, 9 to 19 cm, or 20 to 33 cm. When all depths were grouped, mortality was 82% for plants with roots covered and 5% for plants with exposed roots. Results with the extra-wide blade were not different from uprooting with the narrower blade. These data suggest that the efficacy of commercial uprooting could be improved by covering the roots with soil. A study to determine rates of grubbing at different plant densities was also included. A 30 kW, farm tractor with a rear-mounted grubbing blade was used. Based on the prediction equation, grubbing rates for 200, 300, and 400 plants/ha would be 1.08, 0.82, and 0.69 ha/h.


Notes: How can we make the patterns of fire in space and time visible? How can academic knowledge be translated into everyday knowledge. The power of fire need to be seen as a quintessential part of the environment and a shaper of our lives. This is something we can learn from the Hawaiians and other indigenous cultures.

Williams J. E. (2005) *Native Vegetation and Regional Management: a guide to research and resources*. Greening Australia Ltd, Yarralumla ACT.

Notes: Fire is an integral part of the ecosystem function of the Australian landscape and has been a driving force in the evolution of plant and animal species. A fire regime is comprised of the type, frequency, season and intensity of fires at a particular location. It is difficult to define what is an appropriate fire regime, especially as there is well documented variation through history and this is now more complex if the impact on life and property is included.


Abstract: From the many general statements that can be made about present-day arid Australia there are three of particular significance to the biota: the marked spatial heterogeneity of an immense landscape, the spatial and temporal performance of plant species (as competitor for other plants and as food and shelter for animals) and the many
individual plants that pre-date the European invasion of Australia and which do not appear to have replacements. This review of the vegetation of arid Australia draws attention to the patchiness and structure of the plant communities in the desert landscape, treating these communities as an environment for animals and plants

**Notes:** Patchiness / spatial heterogeneity / pattern in vegetation: eg mulga groves and intergroves, gilgai microrelief - changes in water distribution which causes veg change. Patchiness can also be caused by fire and variable soil compaction of soil by cattle depending on their preference for forage across the paddock.

Scale: inputs applied at a coarser scale can upgrade the output. This is exemplified by comparing a range of veg mapping scales.

Major Vegetation formations: Semi-arid shrublands (only down the eastern edge of the arid zone); arid and semi-arid low woodlands; chenopod low shrubland or shrub steppe; Acacia shrublands; Eucalypt shrublands or Mallee; hummock grasslands; arid tussock grassland. See map of these formations across the Australian arid zone.


**Abstract:** Tropical savannas dominate the landscapes of the wet-dry tropics of northern Australia. The savannas are both fire-prone, and relatively intact ecologically, hence the management of biodiversity requires an understanding of the interactions between fire regimes and flora and fauna. Fire is extensive and frequent in Australia's savannas, and most fires are lit by humans. There is regional variation in both the extent and frequency of fire, both being greater in northwestern Australia (northern NT and WA) than in northeastern Australia (Cape York). Fire frequency is higher in mesic savannas than in semi-arid savannas. Fire regimes are the product of consistent patterns, both inter-annually and inter-seasonally, in the occurrence of moderate - severe fire-weather, and the production and curing of fuels. Early dry-season fires are less intense and extensive than late dry-season fires. Across the savannas early dry-season prescribed burning is used extensively in an attempt to reduce the extent and impact of late dry-season fires. The ecological effects of fire vary with intensity and frequency depending on life form. For some components of the biota - e.g. much of the ground stratum vegetation, invertebrates, herpetofauna - interseasonal conditions in moisture appear to be a more forceful determinant of community composition and structure than fire. Tree mortality is higher following late dry-season fires than early dry-season fires. While there are species and communities in the savannas that can persist in the landscape in the face of frequent fires, the abundance of some plant life-forms (e.g. obligate seeding shrubs), and some animals (some medium-sized mammals), and seedling recruitment in some dominant eucalypts may be reduced by frequent fires. Further research is required to integrate point based studies of fire impacts with a spatial understanding of ignitions, fire behaviour and ecosystem dynamics.
The distinct seasonality of rainfall is a primary determinant of both biota and fire regimes of the region. The combination of regular wet season rainfall and an extended warm, dry season produces fine grassy fuels, which cure every year. There are also high rates of ignition due, in the past to lightning and at present to both planned and unplanned ignitions across almost all land tenures. Fire is both frequent and extensive. 

**Fuels:** Fine fuels - grass and tree leaf litter and leaf and twig components increased as the dry season progresses due to leaf fall in both deciduous and evergreen trees.

Impact of fire in the savannas need to be seen in the context of timing, frequency and intensity of fire - fire regimes - in relation to critical life-history processes.


**Abstract:** The management of fire in savannas has been informed by a strong tradition of fire experiments, especially in Africa. This research tradition is much shorter in the 2 million square kilometres of tropical savannas in northern Australia, but has yielded several natural experiments, and three designed, manipulative, controlled field experiments (hereafter 'manipulative' experiments) of international significance (at Munmarlary, Kapalga and Kidman Springs in the Northern Territory). Here we assess the contributions of experiments, in particular the manipulative experiments, to ecological understanding and biodiversity management in Australia's savannas. Running from 1973 to 1996, the Munmarlary experiment comprised hectare-scale experimental plots with four replicated dry season fire treatments, and was designed to examine interactions between fire, landscape and biodiversity. The Kapalga experiment ran from 1989 to 1995, with a range of fire treatments broadly similar to those at Munmarlary. However, experimental units were 10–20 km2 sub-catchments, making it one of the largest, replicated fire experiments ever conducted. The Kidman Springs experiment focused on grass-layer productivity and composition to meet the needs of the pastoral industry, but also provided an opportunity to examine biodiversity responses to different fire regimes. Methodologically, the experiments have generally focused on phenomena—the responses to different fire treatments of individual taxa—rather than on mechanisms that determine response syndromes. They have highlighted that a range of responses to differences in fire regime is possible, and that no single fire regime can optimise all biodiversity outcomes. For effective conservation of biodiversity in the face of such complexity, conservation goals will need to be made explicit. The existing portfolio of manipulative experiments is incomplete, lacking especially a consideration of some critical savanna taxa and environments, and providing little information on the significance of spatial and temporal variability in fire patterns, especially at small scales. An understanding of fire in Australian savanna landscapes remains inadequate, so there is a continuing need for close partnerships between scientists and conservation managers, with fire management treated as a series of landscape experiments in an adaptive management framework.

**Abstract:** Discusses: The Grazing Process (Species selection, spatial distribution of grazing); Nutritional Value of Rangeland Forages (energy, protein and minerals; ephemerals, perennials and browse - high quality/low stability to high stability/low quality; the impact of grazing on plant communities); Differences between sheep, and cattle, goats, kangaroos and rabbits (selectivity; production characteristics); Impact of Aridity and Climatic Variability on Productivity (growth and reproduction; livestock numbers year to year variation and drought; environmental extremes).

**Notes:** Grazing selectivity between species - goats generally eat more browse than sheep but they obtain most of their forage from the same herbage species as sheep; kangaroos eat mainly grass, rabbits eat anything green and bark. There are differences between animal species in their dietary selectivity; cattle are less selective, goats consume more browse and kangaroos more grass than sheep. However the differences are small and all prefer and compete for the main herbaceous species.


**Abstract:** Discusses: Stocking rate and Intensity (Immediate effect of stocking intensity on animal productivity; long term effects of stocking intensity on animal productivity; utilisation; stocking strategies; carrying capacity); Grazing Systems (Principles; practice); Composition of Animal Populations (choice of herbivore; impact; vegetation management) Animal Distribution (fencing; water); Conclusion.

**Notes:** Heavy goat grazing will reduce vegetation to its least palatable components but when stocking rates are controlled at sustainable levels goats are no more damaging than other herbivores. Kangaroo populations are probably higher than they were pre-European settlement and can remove all herbage as do sheep when in high aggregations.


**Abstract:** The regeneration of several shrub and tree species in western New South Wales was recorded after widespread natural fires in the summer of 1974/75. At 25 locations, plots
were established in the wake of the fires and observations were recorded of the fire damage, the regrowth of the plants and post-fire seedling establishment. Interest was centred on species regarded as woody weeds. Fourteen months after the fires, the average survival of seven of the most common species was: *Callitris columellaris* (white cypress pine) 2%, *Acacia aneura* (mulga) 16%, *Dodonaea attenuata* (narrow-leaved hopbush) 26%, *Cassia eremophila var. platypoda* (punt) 48%, *Acacia homalophylla* (yarran) 87%, *Eremophila mitchellii* (budda) 88% and *Eremophila sturtii* (turpentine) 87%. These results are for plants whose leaves were totally scorched or burnt. For *Dodonaea attenuata* and *Cassia eremophila* there was a large difference in recovery between locations, a difference which was not explicable in term of fire intensity or shrub size. Post-fire seedling establishment occurred with these two shrubs, particularly with *D. attenuata*, which had high seedling numbers on eight of the eleven locations.

**Notes:** Although fire intensity, seasonality, and frequency could not be included in this study the response of woody shrubs to the 1974-5 wildfires in the Cobar-Byrock area was assessed. Unburnt control sites were included and plant deaths were insignificant. Survival on burnt sites: White Cypress 2%, Hopbush 26%, Cassia 48%, turpentine 87%, buddah 88% but marked variation between sites. Conclusions: Cypress & mulga susceptible to fire and could be controlled by fire but necessary to determine relationship between plant size, density and fuel availability to optimise the control when the infrequent opportunities arise. Most effective on small plants. Reasons for variable response by cassia & hopbush not clear. Generally supports the potential for controlled use of fire for shrub control. Management regimes may need to be specific to types of country. Necessary to explain the relationship between plant size, density and fuel to make optimum use of infrequent opportunities for burning and determine when plant are beyond the size for effective control given the amount of ground fuel present.


**Abstract:** In an arid (275 mm rainfall) belah (*Casuarina cristata*), rosewood (*Heterodendrum oleifolium*) woodland, goat does of feral origin and Merino ewes were grazed separately or in mixed groups to determine the relative effects of the different combinations on the shrub and herbaceous vegetation, and on total animal production. The goats browsed the accessible foliage of trees, but did not obtain a substantial amount of their forage from that source. Thus they were competitive with sheep for the herbaceous layer (principally *Stipa variabilis* (variable speargrass) and *Sclerolaena* spp. (copperburrs). Grazing sheep and goats together did not achieve greater animal production than grazing them separately. Under drought conditions, those sheep grazing in conjunction with goats lost weight sharply in comparison with the goats, or to other sheep grazing without goat competition. The weights of the kids born in this trial were only 60% of the weights of the lambs, at both weaning and 1.5 years of age, although the net reproduction rate of does (120%) was twice that of the ewes
Goat grazing did not suppress the unpalatable shrubs. It is concluded that the grazing of feral goats either alone or mixed with sheep, will not result in higher animal production or shrub control in this woodland community.


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3. Methods: Resampling of localities
4. Results: Presence of possum at sampled localities; disappeared populations; Reappeared populations; Continuously present; Appeared; Never seen; Population nodes; Woodland types used by Common Brushtail Possums; Tree characteristics; The regional population of Common Brushtail Possums; Structure of the Cape York Population
5. Possums: declining of not?
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8. What next? Biology of the Common Brushtail Possum (diet, population ecology and behaviour); Environment of the Common Brushtail Possum (habitat structure, soil fertility, tree hollows as daytime shelter, fire grazing, refugial areas, climate).
9. References.


Abstract: Birds and reptiles were censused at two sites of contrasting soil texture (clay, loam) on pastoral land in the Victoria River District, Northern Territory. Both sites comprised 16 plots (each of 2.6 ha) subjected to seven different experimental fire regimes (unburnt, burnt in the early dry season at 2, 4 and 6 year intervals, and burnt in the late dry season at 2, 4 and 6 year intervals) beginning five years before sampling (and thus, not all regimes had been operationally distinct between the onset of the experiment and this sampling). The regimes were deconstructed to four fire factors: the imposed regime, the time since last fire, the number of fires since the inception of the experiment, and the number of hot (=late dry season) fires. Of 30 species recorded from at least four plots, 12 were significantly associated with time since last fire. These responses were mostly to the extremes - some species were associated with the most recently burnt areas, and others occurred mainly in the plots which had been unburnt the longest. Longer-term responses to fire regimes were generally less
clearcut, possibly because the relatively short duration of the imposed experimental fire treatments had not yet brought about substantial environmental divergence.

**Notes:** On a national scale an inappropriate fire regime is one of the most important factors affecting threatened bird species and is recognised as a threat to other vertebrate groups. Aboriginal land management has been replaced with pastoral management resulting in changed fire regimes across the rangelands, usually a reduction due to deliberate suppression or consumption of fuel by stock - results in the increased dominance by woody plants in many areas.

Short term responses - many bird species attracted to recently burnt areas - mostly granivores; bird species preferring the relatively dense tall grass or understorey vegetation and several arboreal species were least abundant in the recently burnt plots. Overall the results of this study show few differences between the longer-term impacts of early and late dry season fires except for some species eg Blind Snakes.


**Abstract:** There has been substantial loss of biodiversity in the Australian rangelands, and evidence suggests that the attrition is continuing. We argue that rangeland users should be more aware of, and concerned about, this problem: that we are sullying an international asset; that we are undermining the basis of a major rangeland industry, tourism; that we are sabotaging the potential for the development of alternative rangeland uses (most notably sustainable use of native wildlife); that such losses provide evidence that we are poor managers; that such losses diminish our lives; that such losses indicate that at least some of our environments are operating at reduced functionality; and that such losses take away or reduce important and wide-ranging environmental services.

This loss is due to a complex array of factors, each affecting different components of biodiversity in different ways. Our responses are generally poorly coordinated across rangeland jurisdictions, and there is uncertainty about responsibilities across different land tenures. Given the diffuse but pervasive nature of the problem and the generally poorly coordinated and non-strategic current response, we suggest that biodiversity conservation needs to be far more clearly and systematically operationalised, that a clear goal for biodiversity conservation in the rangelands (maintenance of viable populations of all native species of plants and animals at appropriate spatial and temporal scales) needs to be developed, and that, from this, the community needs to set explicit targets relating to this goal, at continental, jurisdiction, regional and property scales. While we recognise that our existing knowledge base is imperfect, such limitation should not delay the implementation of these steps. We consider that there is sufficient management expertise to realise a rangeland biodiversity goal. However, there are two more serious impediments in achieving the goal: current lack of resources and of societal agreement.
Notes: Discusses the status of biodiversity in the rangelands. Primary cause of change is that we have changed the management fabric of the continent from thousands of years of Aboriginal management which had reached and environmental equilibrium which has now been changed. 15-40% of species have decreased in response to grazing pressure across all biotic taxa. Rangeland Biodiversity affected by many factors in addition to pastoralism including altered fire regimes, spread of pests and exotic plants, hunting or other forms of use, vegetation clearing, climate change and others plus combinations of these. Also discusses the future for biodiversity in rangelands.


Abstract: The literature concerning the impact of fire on avian communities and the response of birds to fire is reviewed for the Australian continent. There are few detailed long-term studies of the effects of fire on avian communities, but there is sufficient information on fire effects from a broad cross-section of Australian habitats to identify patterns of response to individual fires and to predict the likely long-term effects. Some birds respond immediately to fire, taking advantage of temporarily increased availability of food. These birds include predators that are attracted to fires to feed on exposed, disoriented and fire-killed prey and seed-eaters that congregate in burnt habitats to feed on seeds released by the fire or on seeds of rapidly maturing post-fire ephemerals. At least in eucalypt forests, there is an increase of arthropod abundance on the rapidly regenerating vegetation that may lead to increased abundances of some bird species. Depending on the severity of the fire and the amount of vegetation killed, most avian communities recover rapidly following single fires regardless of fire intensity. However such fires may pose a significant threat to species with a restricted distribution, limited reproductive potential, poor dispersal ability and/or narrow habitat requirements. Birds persisting in fragmented habitats are particularly at risk. However, of greatest significance as a threatening process to avian communities are increases in fire frequency.

Of the threatened species in Australia whose relationships with fire have been comparatively well documented, almost all show a clear preference for less frequent fires. Detrimental fire regimes contributed to the extinction of two of the three bird species and three of the four sub-species which have disappeared from Australia since European colonisation. Inappropriate fire management is now a factor in the threatened status of at least 51 nationally recognised threatened Australian bird taxa. In many environments (notably heath and mallee) inappropriate fire regimes are the main threat to declining bird species. In temperate eucalypt forest and woodland, as well as i heathlands, control burning is widely used to reduce the threat of wildfire. While, in general the immediate impact of controlled burns is less than that of wildfire, the frequency of these fires can lead to floristic and structural changes in the vegetation. Although not well documented, these low-intensity fires may lead to the decline and loss of some species which are now perceived as common and little affected by mild fires.

Notes: Short-term effects of fire in hummock grasslands of central Australia include invasion
of burnt areas by nomadic open-country birds. Pioneer plants in grasslands provide a rich seed resource soon after fire and many granivores are attracted to recently-burnt areas. Recently burnt mulga contains many generalist nomadic species. As the abundance of food available after a fire declines, birds originally attracted are replaced by birds of open habitats. In tropical open forests and woodlands few birds are disadvantaged in the short term. Hot fires late in the dry season may destroy hollow bearing trees. After intense fires in which canopy trees are killed species typical of old growth forests may still be absent or uncommon 50 years later. The pattern and rate of change of species abundances following fire differs according to habitat, floristics, fire history climate, patch size and isolation and the patchiness of the fire. Describes sequence of recolonisation in mallee and mulga woodlands. The long term effects in shrublands and grasslands are not clear.

Fire imposes a dynamic pattern on the structure and floristic composition of plant communities but the mosaic of vegetation age classes and habitats created by serial events is only part of the complexity created by fire - it also affects the abundance, distribution and size of litter and dead woody material as well as of individual plants. Too frequent fires deplete soil organic matter and nutrients adversely affecting vegetative structure and species richness and ecosystem functions such as nutrient and hydrological cycles. Understanding the response of the biota to fire is fundamental to managing fire prone environments, conserving biological diversity and protecting ecosystem processes and functions.


**Abstract:** This opportunistic study compares the vegetation, fuel loads and vertebrate fauna of part of a 120-ha block of tropical open forest protected from fire for 23 years, and an adjacent block burnt annually over this period. Total fuel loads did not differ significantly between the unburnt and annually burnt sites, but their composition was markedly different, with far less grassy fuel, but far more litter fuel, in the unburnt block. There were major differences between treatments in the composition of trees and shrubs, manifest particularly in the number of stems. There was no overall difference in plant species richness between the two treatments, but richness of woody species was far higher in the unburnt treatment, and of annual and perennial grasses, and perennial herbs in the annually burnt treatment. Change in plant species composition from annually burnt to unburnt treatment was directional, in that there was a far higher representation of rainforest-associated species (with the percentage of woody stems attributable to ‘rainforest’ species increasing from 24% of all species in the annually burnt treatment to 43% in the unburnt treatment, that of basal area from 9% to 30%, that of species richness from 8% to 17%, and that of cover from 12 to 47%). The vertebrate species composition varied significantly between treatments, but there was relatively little difference in species richness (other than for a slightly richer reptile fauna in the unburnt treatment). Again, there was a tendency for species that were more common in the unburnt treatment to be rainforest-associated species. The results from this study suggest that there is a sizeable and distinct set of species that are associated with relatively long-unburnt
environments, and hence that are strongly disadvantaged under contemporary fire regimes. We suggest that such species need to be better accommodated by fire management through strategic reductions in the frequency of burning.


**Abstract:** There are many uses for prescribed burning in the management of forests, chaparral, grasslands watersheds and wildlife. Some of these uses have been pointed out in this paper. There are also many dangers in using fire, both in its application and in its results. To minimise harmful effects fire should never be used during extended dry periods; burns should always take place when the soil is damp or wet. Moreover the used should be an experienced professional with a thorough knowledge of ecosystems, weather and fire behaviour.

**Notes:** Few land managers have the training or courage to conduct a burn. Most have been exposed to catastrophic fires which are untimely, have undesirable effects and scare everyone in their paths. Another fear includes liability for an escaped control burn. Burning has the advantage of stimulating growth of other groundcover plants, not achieved by chemical control. Management after a burn is essential for obtaining desirable results - must be done on a manageable unit basis. For years forests protected by foresters whose training was dominated by European philosophy. This was the wrong approach because most forests evolved with fire. Without the natural sequence of fire north American forests have become plagued by inadequate reproduction, overstocking, stagnation, diseases and insects as well as excessive fuel accumulation.


**Abstract:** Fire is an effective tool to control shrub growth, remove excess litter, increase forage yields, increase palatability of coarse grasses, control grass species, and remove woody debris in semi-arid rangelands in good condition. However, rate of shrub reinvasion depends on grazing management. Maintaining a healthy herbaceous cover is essential to slow shrub re-invasion and to enable continued use of fire as a cheap maintenance tool at the desired frequency. Fire frequencies should generally not be more than 5 to 10 years in semi-arid grasslands and may not be needed more often than 50 years in some areas. Where there are mixtures of sprouting and non-sprouting species, the burning interval should be at least 20 years so that the seed obligate species have time to produce seed before the next fire. The composition of a plant community should be studied in detail before initiating a burn. The result of a burn is what you see, but the species composition can change dramatically from a few years to 50 or more years after a burn, especially if non-sprouting woody species are
Notes: Suggests that in North America fire occurred every 5-100 years in semi-arid rangelands and less often in arid systems. The primary impact of fire on semi-arid grasslands was to slow or stop the invasion of non-sprouting shrubs and to reduce the cover on non-sprouting species. Density of shrubs remained the same after fire but herbaceous species were more productive. Fires in arid plant communities occur after high rainfall allowing annuals to grow and they are generally devastating. In semi-arid rangelands most natural fires occurred during drought and were extensive. To optimise productivity - now recommend burning when there is good soil moisture, grasses and forbs recover quickly. Overgrazing is one of our most serious problems in semi-arid shrub-grasslands - reduction in competition caused by overgrazing favours woody species.


Abstract: Aim
To compare fire behaviour and fire management practice at a site managed continuously by traditional Aboriginal owners with other sites in tropical northern Australia, including the nearby Kakadu National Park, and relate those observations to indicators of landscape condition.

Location
Dukaladjarranj, a clan estate in north-central Arnhem Land, in the seasonal tropics of northern Australia. The site abuts a vast sandstone plateau that is an internationally recognized centre of plant and animal biodiversity.

Methods
Ecological assessments included: (1) mapping of the resource base of the estate from both traditional and ecological perspectives; (2) aerial survey of the extent of burning, distribution of the fire-sensitive native pine *Callitris intratropica*, rock habitats, and a range of macropod and other fauna resources; (3) fauna inventory; (4) detailed ecological assessment of the status of fire-sensitive vegetation; and (5) empirical assessment of the intensities of experimental fires. Ethnographic information concerning traditional fire management practice was documented in interviews with senior custodians.

Results
Experimental fires lit during the study were of low intensity compared with late dry season fires reported elsewhere, despite weather conditions favouring rapid combustion. In contrast to other parts of the savanna, fuel loads comprised mostly leaf litter and little grass. We found that (i) a large proportion of the estate had been burned during the year of the study (ii) burned sites attracted important animal food resources such as large macropods (iii) important plant foods remained abundant (iv) well represented in the landscape were fire sensitive vegetation types (e.g. *Callitris intratropica* Baker & Smith woodlands) and slow
growing sandstone ‘heath’ typically dominated by myrtaceaous and proteaceous shrubs (v) diversity of vertebrate fauna was high, including rare or range-restricted species (vi) exotic plants were all but absent. Traditional practice includes regular, smaller fires, lit throughout the year, and cooperation with neighbouring clans in planning and implementing burning regimes.

Main conclusions
We attribute the ecological integrity of the site to continued human occupation and maintenance of traditional fire management practice, which suppresses otherwise abundant annual grasses (Sorghum spp.) and limits accumulation of fuels in perennial grasses (Triodia spp.) or other litter. Suppression of fuels and coordination of fire use combine to greatly reduce wildfire risk and to produce and maintain diverse habitats. Aboriginal people derive clear economic benefits from this style of management, as evidenced by abundant and diverse animal and plant foods. However, the motives for the Aboriginal management system are complex and include the fulfilment of social and religious needs, a factor that remains important to Aboriginal people despite the rapid and ongoing transformation of their traditional lifestyles. The implication of this study is that the maintenance of the biodiversity of the Arnhem Land plateau requires intensive, skilled management that can be best achieved by developing co-operative programmes with local indigenous communities.


Abstract: The current status of Australia’s rangelands reflects the lack of a coherent philosophy for their management and in many situations this has resulted in their abuse and degradation. Unless we develop a clear management philosophy for these lands and express it through a set of general aims and specific objectives we must expect these lands to continue to decline in condition. We must also stop ‘passing the buck’ and determine who is responsible and who should be accountable for achieving which objectives.

Notes: Issues discussed include: maintain productive potential, maintain adaptive social structures, preserve genetic diversity, develop heritage and cultural values, encourage joint and multiple land use, restore degraded land.