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Rangeland Management in Western Australia

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Rangeland Management in Western Australia

Contents

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Forty per cent of Western Australia is rangeland where rainfall is inadequate for growing crops but sufficient to support grazing of livestock. The Rangeland Management Branch of the Department of Agriculture has the responsibility of working with pastoralists to ensure these lands are managed today for the continued use of generations to come.

This series of articles outlines some of the activities of the Department as it strives for an understanding of the ecological principles behind rangeland management and rehabilitation. These principles are the framework for the rangeland survey and monitoring programmes and are used to provide practical management advice to the pastoral community, mining companies and other users of pastoral lands, all of whom are covered in this publication.

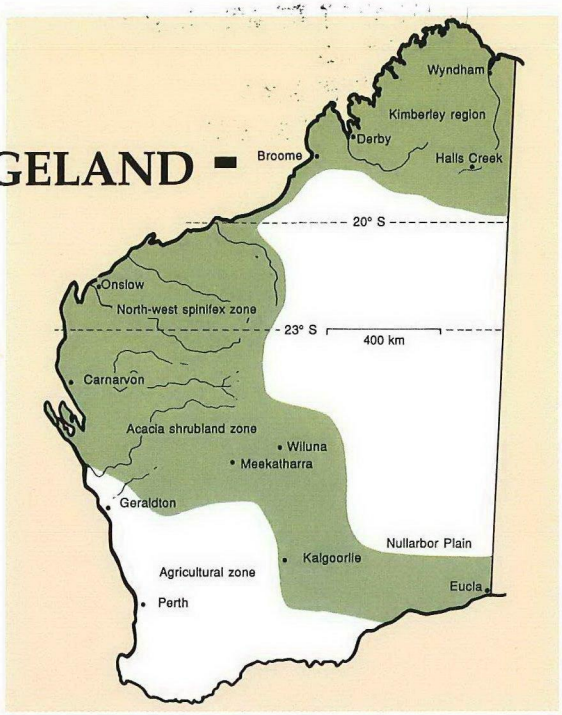
GRAZING THE RANGELAND - towards an understanding

By Alec Holm, Manager, Arid Pastoral Region, Carnarvon and **Donald Burnside**, Officer-in-Charge, Kalgoorlie

Western Australia's rangelands are those parts of the State, excluding deserts, where inadequate rainfall prohibits their development for a cultivated agriculture. About 980,000 sq. km of these rangelands are held as pastoral leasehold land, with a total of 450 individual station businesses. These native pasture lands support about 2.5 million sheep and 850,000 cattle.

The rangelands can be divided into three main natural regions, each of which has a distinct climate and vegetation. These are the Kimberley region; the north-western spinifex region, which includes the Pilbara; and the Acacia shrubland region of the Gascoyne, Murchison, Goldfields and Nullarbor areas.

This is the first in a series of articles in the Journal of Agriculture on research by the Department of Agriculture's Rangeland Management Branch.



The shading shows Western Australia's pastoral areas.

Bluebush pastures in good condition in the rangelands.

The Kimberley region

The Kimberley region lies north of latitude 20°S in a tropical monsoon zone. Almost all the useful rainfall is in summer, from December to March. The average annual rainfall varies from 1150 mm on the north coast to 500 mm and less inland.

The main pastures are native tussock and hummock perennial grasses, and the most valuable pastures are those of the extensive grassy plains adjacent to the major river valleys of the Ord, Fitzroy and Margaret Rivers. The most useful grasses are the Mitchell grasses (Astr*ebla* spp.), the ribbon grasses (*Chrysopogon* spp.) and the introduced buffel and birdwood grasses (*Cenchrus* spp.). Pasture quality is excellent during and immediately after the wet season (January to May), but declines during the dry winter and spring. Low quality spinifex (*Triodia* and *Plectrachne* species) pastures are widespread and are grazed by cattle mostly after burning in a late dry season.

There are about 600,000 cattle in the Kimberley. The individual cattle stations are large enterprises running up to 40,000 head of cattle per station. Most cattle are maintained as open range herds obtaining water from river pools and billabongs and from pumped underground supplies away from the rivers. Fat and store cattle are turned-off in winter. The historical "turn-off" percentage has been between 10 and 15 per cent of total herd numbers.

The north-western spinifex region (the Pilbara)

The north-western spinifex region lies between the Kimberley and latitude 23°S. The climate is semi-arid with an unreliable rainfall of 200 to 300 mm annually, mainly in summer in association with the passage of tropical cyclones. No pastoral development has occurred east of 122°E, where permanent grazing and water are not available.

The dominant pasture plants are the many species of spinifex , some of which are palatable to grazing animals, but many are not. Plant nutrient levels are generally poor, except in the periods immediately after useful rain. Periodic managed burning can maintain these pastures in an ecologically stable and productive state. Nevertheless, the level of animal production from areas dominated by spinifex

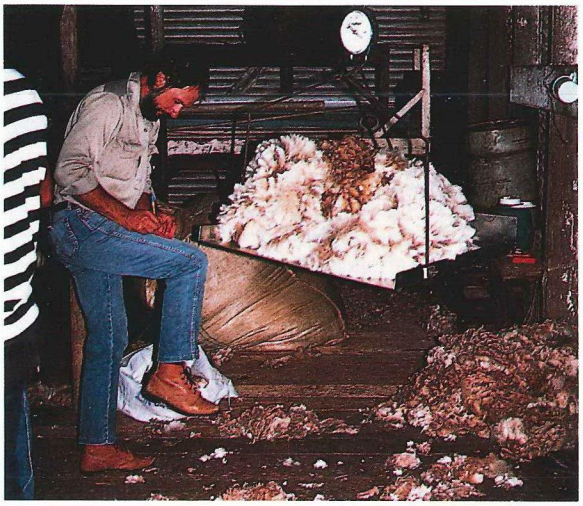
Surveys of Western Australia's rangelands

Report date	Region	Area (sq. km)
1972	Gascoyne River Catchment	63,200
1979	West Kimberley	89,600
1979	Nullarbor Plain (part)	47,400
1982	Ashburton River Catchment	93,600
1988	Carnarvon basin	74,500

is low. The more favoured grazing areas in this region are along river frontages, on the coastal plain and on the "tablelands" associated with the Hamersley and Chichester Ranges. These lands support more palatable and useful perennial tussock grasses similar to those growing in the Kimberley. Buffel and bird-wood grasses are well established on alluvial soils near the rivers. They help stabilize the soil and are a useful feed.

Sheep graze the coastal plain while cattle graze the open range inland. Productivity from properly managed cattle can be acceptable, but poor pasture quality for much of the year limits sheep production to about two kilograms of clean wool per adult sheep. Stocking rates, however, are higher than in the more sensitive shrublands further south.

Two-year-old river saltbush established from seed on degraded land near Leonora.



Weighing fleeces as part of a major grazing study near Carnarvon.

The shrubland region - Gascoyne, Murchison, Goldfields and Nullarbor areas

The semi-arid shrublands occur across the southern half of Western Australia, below latitude 23°S. They are adjacent to the agricultural area, the margin between the outer wheatbelt and the shrublands usually being drawn along the 250 mm rainfall isohyet. The climate is semi-arid, with an unreliable rainfall of 150 to 250 mm annually. Most useful rainfall is in winter. The region experiences occasional lengthy droughts and there are many years when the rainfall is below average.

The shrubland supports a rich and diverse plant life. It consists of a tree layer, a perennial shrub layer, hummock and tussock perennial grasses and short-lived grasses and herbs. Acacias dominate the tree layer, except in the Eastern Goldfields where they are replaced by Eucalypts. The most common Acacias are snakewood (*A. xiphophylla*) which grows in the West Gascoyne, mulga (*A. aneura*) which is found from the Upper Gascoyne through the Murchison to the North-Eastern Goldfields and myall (*A. papyrocarpa*) which is dominant on the margin of the Nullarbor Plain.

The important pasture plants are the shrubs, perennial grasses and annuals which can provide the grazing animal with a diet high in the required nutrients. However, because of the erratic and infrequent rainfall, stocking rates must be kept low for the pastures to be maintained in a healthy state and for stock to graze an adequate diet during dry periods. Stocking rates on these pastures can vary from one sheep to eight hectares on good quality saltbush-bluebush to one sheep to 24 hectares on mulga-short grass pastures.

Sheep grazing is the major pastoral activity in these areas. A typical station runs between 8,000 and 10,000 sheep on an area of 100,000 to 200,000 ha. Sheep are run in large paddocks averaging 7,000 ha. An average station will have from 30 to 60 permanent watering points. Wool production provides nearly all of the station income, but the proceeds from the sale of sheep have improved significantly in recent years.

The ecology of rangeland plant communities

The pastoral industry relies on a range of native trees, shrubs and grasses forming many separate plant communities. An understanding of the ecology of these communities, and the influence of grazing upon them, is essential if the Department of Agriculture is to provide meaningful advice to the pastoral industry on rangeland management.

"Exclosure" studies

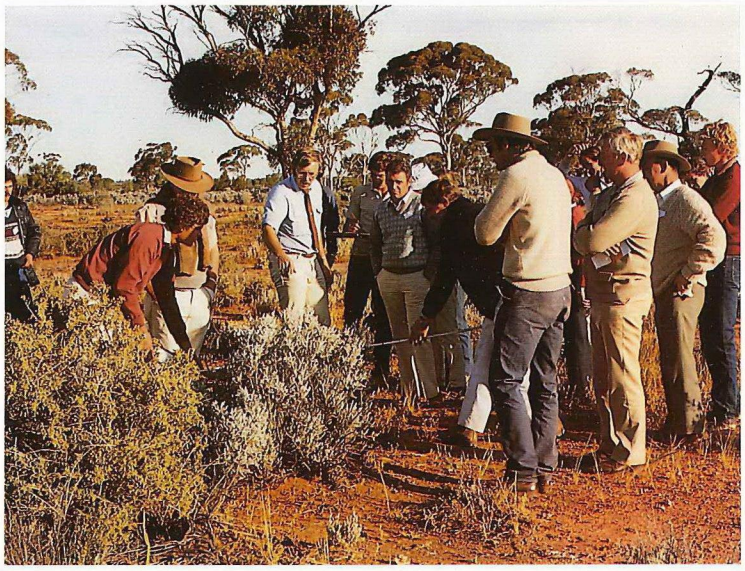
An important technique in assessing how rangeland plants respond to grazing is to erect fenced "exclosures" to keep out grazing stock. There areas usually cover about four hectares and provide reference sites for studies of plant changes within the more important plant communities. The first exclosures in the pastoral areas were built in the Murchison in 1951, and a network of sites now exists from the Kimberley to the Goldfields.

Rangeland surveys

The Department Agriculture's Rangeland Management Branch and the Department of Land Administration are committed to a programme of mapping and describing the State's pastoral lands (see Table). The surveys provide a comprehensive description of the pastoral resource in terms of land form, vegetation and soil.

They assess the pastoral potential of the various land systems and pasture communities, as well as the effect of grazing on the range resource on each pastoral lease. They are intended as management aids for pastoral managers, rangeland advisers, Soil Conservation District Advisory Committees and land administrators.

Since the surveys first began with field work in the Gascoyne Catchment in 1969, some 368,300 sq. km of pastoral lands have been surveyed and mapped (see map and table). The survey team is now working in the Murchison River Catchment (80,000 sq. km), in the Roebourne Plains (about 10,000 sq. km), and the North-Eastern Goldfields (92,000 sq. km).



□ Pastoralists at a field day at Gindalbie Station discuss the use of WARMS - the Western Australian Range Monitoring System.

Performance of livestock

The nature and condition of different parts of the rangelands and the different management practices adopted by pastoralists produce variations in livestock performance. More needs to be known about animal behaviour and performance in the pastoral areas, and research in this field has a high priority in the Department's rangeland management programme.

Studies of sheep reproductive behaviour from the mid 1960s at Wiluna, in the lower Murchison, at Carnarvon and at Meekatharra determined that nutrition of the ewe throughout the reproductive process had a major influence on lambing percentages. The use of this information, associated with a knowledge of the nature and performance of different types of pasture, has allowed some pastoral managers to achieve lambing percentages above the State average of 70 per cent.

The Department of Agriculture started detailed studies to assess the performance and sources of reproductive loss in pastoral cattle in the East Kimberley and north of Meekatharra in 1979, and in the Pilbara near Port Hedland in 1980. Some of these studies assessed the effect of basic management practices such as weaning and culling for age on herd productivity. Studies of different beef breeds have shown that the use of zebu (*Bos indicus*) type cattle in cross breeding programmes in northern rangelands can improve cattle productivity above that of pure Shorthorns.

A century of G R A Z I N G use

Rangelands used for grazing are leased from the Crown and are administered by the Minister for Lands through the Pastoral Board. Leases are long term and annual rentals are low.

Most pastoral lands were grazed by the 1890s. The only significant grazing developments since then were in the Goldfields (following the gold rushes) and on the Nullarbor which was little used for grazing before the 1960s. The early use of the rangelands concentrated on the most productive pastures along the river valleys and where water was readily available. Later pastoral development extended into less productive areas with poorer pastures.

The early pastoralists, encouraged by initial high levels of animal production, the ease of development and management, and the government policy of the day, allowed stock numbers to climb to 5.5 million sheep and 700,000 cattle by the mid 1930s. An unprecedented severe drought over all pastoral areas south of the Pilbara from 1935 to 1942 halved stock numbers in the area, and exposed a serious decline in the condition of the vegetation and the soil.

In the Murchsion-Meekatharra area, a Royal Commission in 1940 estimated that 75 per cent of the valuable saltbush (*Atriplex* spp.) and 25 per cent of the Acacias were dead. The Royal Commission on the Pastoral Industry reported many other observations by pastoralists of a serious loss of vegetation and a dramatic increase in soil erosion. It reported that overstocking was common, and that this was the cause of vegetative decline and high animal losses.

The industry recovered from this catastrophe and has stabilized, but sheep and cattle numbers have never again reached their 1930s levels. This reflects a decline in the capacity of the land to support sheep and cattle, and a recognition that previous levels of land use were grossly over-optimistic.

In those areas not affected by this drought, other causes reduced pasture productivity.

In the Pilbara, the mis-use of fire and over-stocking altered the pasture composition from a mixture of spinifex and perennial tussock grasses to poor quality spinifex pastures only. Such pastures lack adequate nutrients to support breeding ewes.

In the Kimberley, the lack of watering points away from the river led to intensive grazing along the productive but fragile river-frontage alluvial soils. By the mid 1940s, widespread erosion and degradation of the grasslands was evident.

One of the few successful pasture plant introductions into the rangelands occurred in the 1920s when buffel (*Cenchrus ciliaris*) and birdwood grasses (*C. setiger*) became naturalized along the alluvial soils near north-west rivers. Pastoralists quickly recognized the value of these perennial tussock grasses and seed was taken into new locations as early as the mid 1920s. This spread of buffel and birdwood grass partially overcame some of the land degradation problems caused by early over-stocking.

In the 1930s, prominent members of the pastoral community recognized the need for a better understanding of the rangeland environment, and began to press for properly conducted scientific studies in the pastoral areas. As a result, early studies into sheep fertility, mulga (*Acacia aneura*) regeneration, sheep numbers and the native spinifex pastures started in the Pilbara and Murchison regions in the 1930s.

The Department of Agriculture located professional agricultural scientists in the pastoral areas for the first time in the early 1950s, and created a separate Rangeland Management Branch in 1971. The Branch's work involves assembling information on the plant and soil resources; basic ecological and grazing management studies; regeneration research and studies of the behaviour and performance of introduced and native grazing animals.

Developing grazing strategies

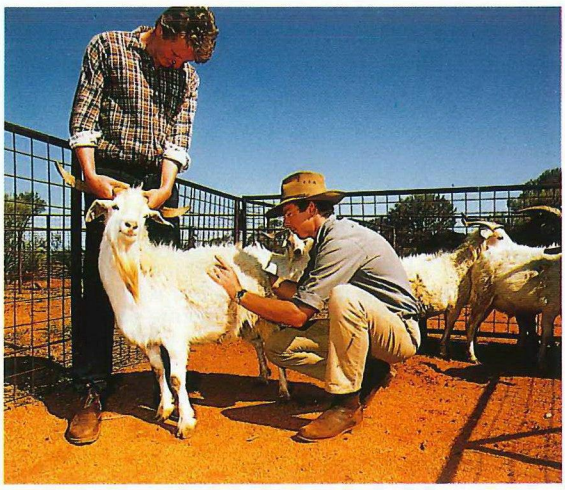
The Department's research into deferred grazing and pasture spelling started at Abydos Woodstock Pastoral Research Station near Wittenoom in 1953. Advisers studied the relationship between burning and spelling paddocks and sheep grazing on spinifex pastures. A combination of burning in summer and deferred grazing improved pasture productivity.

A similar study started on mixed mulga shrubland pastures near Cue in 1981. Early results indicate that sheep prefer to graze stony bluebush pastures to mulga-tussock grass pastures, but there has been no advantage so far from spelling these bluebush pastures.

The first grazing and pasture spelling study in the Kimberley started on the Ord Regeneration Research Station in 1983. It is investigating the effects of pasture spelling and stocking rate of young steers on the rate of improvement of partially regenerated country. Over the five years of grazing, basal ground cover in pastures stocked at 8.3 ha per steer increased by 3 per cent when pastures were spelled over the wet season. The regeneration of Birdwood grass also increased.

Stocking rate studies

In late 1983, sheep were introduced into a ten-year grazing study near Carnarvon to measure the relationship between stocking rate and sheep production. Recent dry years have shown the importance of browse from perennial shrubs. Sheep grazing paddocks with plentiful edible shrubs have maintained wool growth and body weight at all stocking rates, while those stocked at high rates in paddocks with limited shrub feed have had to be removed. Adjusting stocking rates is the most practical management tool available to pastoralists.



☐ Trapping and selling feral goats for meat or as foundation stock for breeding cashmere goats is an additional source of income for pastoralists. This young goat, which is part of a grazing trial in the Goldfields,is being inspected for its cashmere content.

Water supplies and control of animals

The Rangeland Management Branch has helped to develop improved techniques for station fencing and for providing stock watering supplies. Modern fencing designs, researched and recommended by the Branch, are used by pastoralists in soil conservation district rehabilitation projects. The development of cheap, more efficient water supplies allows pastoralists to increase productivity from areas that previously were watered inadequately.

Alternative animals

Sheep and cattle are not the only introduced animals in the rangelands. Feral goats are abundant in the Gascoyne, Murchison and North-Eastern Goldfields. The capture and sale of these goats for either meat, or as foundation stock for the developing cashmere goat industry in the agricultural area, has provided considerable revenue for the pastoral industry in recent years.

A grazing study of the potential for managing a goat grazing enterprise on mulga pastures at Yerilla Station north of Kalgoorlie started in early 1986. Sheep and goats have similar grazing habits in these mulga pastures, and early results indicate that goats reproduce better than sheep on these less productive mulga pastures.

Soil Conservation Districts

The pastoral community has enthusiastically accepted the concept of Soil Conservation Districts. The principal aims of the district advisory committees are the promotion and adoption of managerial practices that will protect and enhance the productivity of the rangelands. Most pastoral areas are now part of a Soil Conservation District, and most advisory committees act as co-ordinators for responsible management of their rangeland resource. They complement the activities of the Rangeland Management Branch and play an important role in determining the nature of the Department's extension activities in their districts.

The Rangeland Resource Surveys will provide a basis for planning for these Soil Conservation Districts. Accurate mapping will help to identify pastoral leases with common types of country within each advisory district for which common management strategies can be developed.

Rangeland regeneration

Unwise and excessive use of pastoral lands in the past has left many areas devoid of useful vegetation and prone to wind and water erosion. The resource surveys mentioned earlier have identified extensive areas where improved grazing management alone will not be enough to rehabilitate these degraded and eroded areas. From the early 1950s, the Department's staff, strongly encouraged by pastoralists, have been developing, testing and implementing rehabilitation techniques for these areas, using a combination of stock control, and cultivation and seeding with suitable plant species.

The outstanding success has been the rehabilitation of the severely degraded and eroded frontages of the Ord River. Thousands of hectares were ploughed and seeded, with the most useful species being buffel and birdwood grasses, and kapok bush (*Aerva japonica*).

In recent years, as part of the National Soil Conservation Programme, research has shown that degraded land in the Gascoyne, Murchison and Goldfields can be rehabilitated by planting desirable pasture plants such as saltbushes (*Atriplex* spp.) and bluebushes (*Maireana* spp.). Similar research on the bare and eroding Fitzroy River frontages is showing that careful attention to plant selection and site preparation can allow perennial grass establishment on these areas.

A new study is investigating the impact that grazing kangaroos have on the regeneration process. The Lyndon Soil Conservation District, north of Carnarvon and including the Exmouth Peninsula, and the Agriculture Protection Board, are co-operating in this study.

□ "Now what has happened since the last inspection?" One of the authors, Donald Burnside (right), and Jim Hurst of Sturt Meadows Station use photographic records produced during rangeland rehabilitation work to assess vegetative changes at one of the monitoring sites.

Other users of rangelands

Because the rangelands are being used increasingly for mining, tourism and the harvesting of native seed, the Rangeland Management Branch provides advice on the additional impact of these activities on the rangelands. The requirements for effective rehabilitation of mine dumps have been studied in Kalgoorlie-Boulder and this work has shown that saltbush and bluebush shrubs can be established on a range of waste materials. (See "Rehabilitation of mined areas and control of dust at Kalgoorlie and Boulder").

Measuring the changes in rangeland pastures

Change in rangeland pastures is often slow and unpredictable. Special techniques are used to measure this change and to record the information in a form that is useful for pastoralists, advisers and land administrators.

The Western Australian Rangeland Monitoring System (WARMS) was developed in the early 1980s to measure seasonal changes in plant communities, as well as those caused by grazing ,throughout the southern pastoral regions. WARMS was developed initially for the shrubland pastoral regions and it will soon be extended to cover the Kimberley and Pilbara grasslands. It provides photographic and demographic records of plant populations at monitoring sites established throughout the pastoral lease. Information on changes in plant population over time will allow pastoralists to gauge the effectiveness of their management decisions on the range resource so that they can use the rangelands responsibly.

Acknowledgement

The Rangeland Management Branch thanks the Australian Wool Corporation, Australian Meat and Livestock Research and Development Corporation, the National Soil Conservation Programme, the Rural Credits Development Fund and the Minerals and Energy Research Institute of Western Australia for their support for much of this research.

RANGELAND SURVEYS:
a basis for improved land use

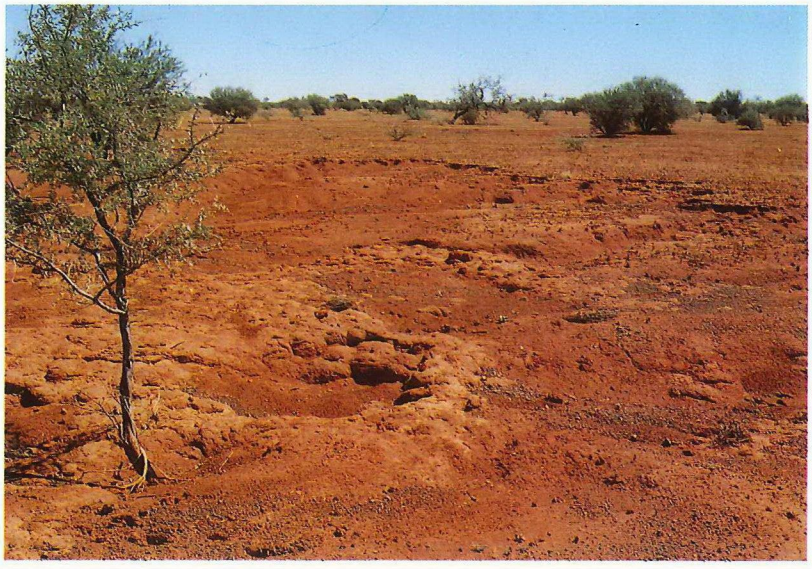
By **Peter Curry** and **Alan Payne,** Advisers, Rangeland Management Branch, South Perth

In mid 1988, the Department of Agriculture started a three-year programme to assist pastoralists in the Murchison River catchment to update land management planning of their stations. This project, which is funded by the National Soil Conservation Program, will use interim results from a recent rangeland survey which has investigated and mapped the grazing resources throughout the region.

Elsewhere in Western Australia's pastoral areas, information on the productive potential of each area - and the management problems inherent for each class of land - are being used to help pastoral managers of Soil Conservation Districts rehabilitate degraded areas. This information will also encourage them to adopt management practices that conserve the land and improve the long-term economic performance of the grazing enterprise.

Contrasting grazing management on pasture and soil conservation on tributary alluvial plains in the upper Murchison.

The above photo taken on Polelle Station near Meekatharra reflects 25 years of conservative stocking and tactical use of paddocks and pastures. The photo below indicates the result of lack of control over grazing intensity on another equivalent area of shallow red duplex soil over red-brown siliceous hardpan.



Statewide surveys

CSIRO carried out the State's first detailed and objective surveys of land resources of arid and tropical areas in the 1950s. Since 1969, the Departments of Agriculture and Land Administration have jointly conducted a continuing programme of rangeland surveys.

Comprehensive surveys have been completed for about 548,000 sq. km of rangeland, or about two-thirds the pastoral land in Western Australia. Fieldwork on a survey of the Murchison River catchment was completed in early 1988, while work on the next major area, the north-eastern Goldfields, started that same year. Rangeland surveys of the remaining areas of the State's pastoral lands should be completed by the year 2000.

Surveys and monitoring

Two important tools to help pastoralists improve their use of the rangelands are the rangeland survey and rangeland monitoring.

Rangeland surveys

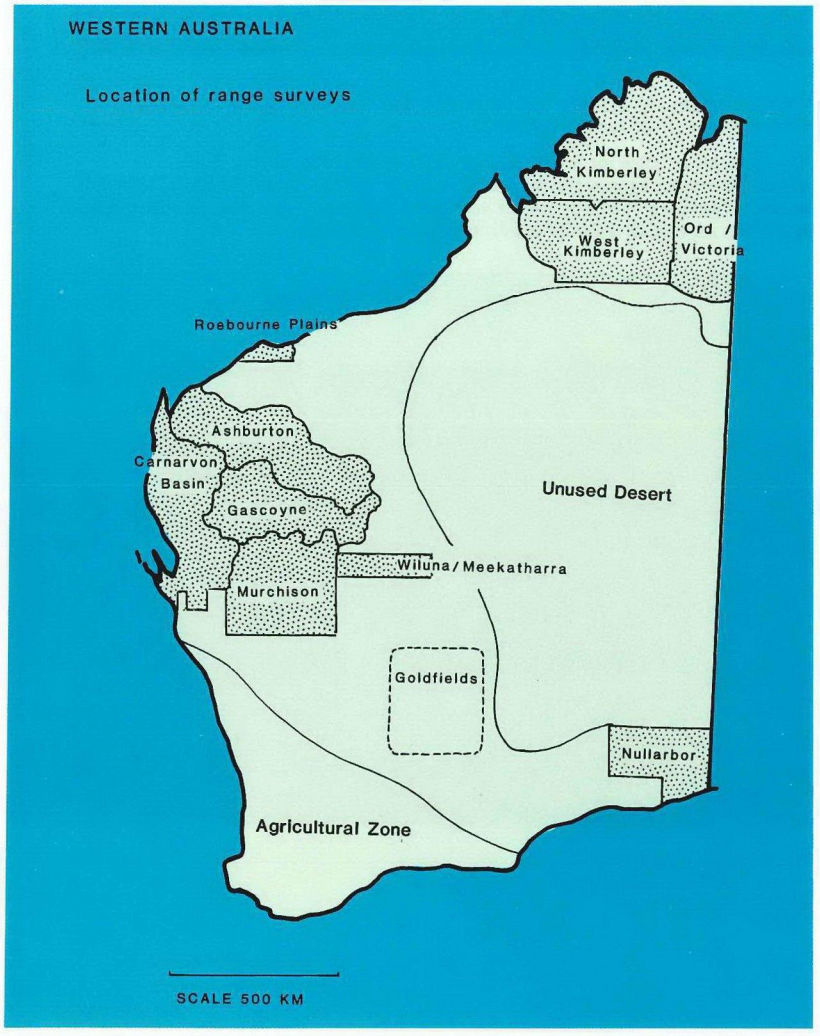
A rangeland survey of a region provides thorough, once-off descriptions of the naturally occurring land systems and vegetation as they relate to grazing usage. These data are then transformed into land classification maps. Where surveys have not been undertaken, existing knowledge and maps of the land and vegetation are generally inadequate as a basis for planning improved grazing practices and station infrastructures.

When all data from a rangeland survey are assembled they provide the first clear indication of the relative proportions of well-preserved land and degraded pastoral land throughout the region (Table 1).

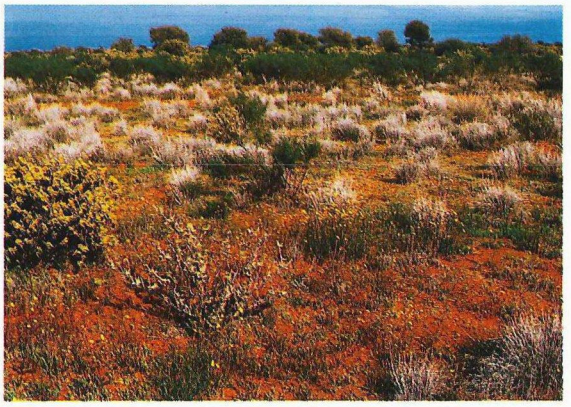
If 60 per cent of the land in a region is now in fair or poor condition, it means that this proportion is now less or much less productive than it was originally. Much of the country in poor condition was formerly the best in terms of its productive potential. This is often the land that was initially over-used and unwittingly degraded many years ago and has not since had the chance to recover.

Between 1 and 2 per cent of the total pastoral area surveyed so far is in poor condition and is severely degraded and eroded to the point that only strict control of grazing, combined with expensive rehabilitation works, will reverse the self-perpetuating processes of accelerated erosion and loss of suitable soil niches for plant germination. Because of the importance of these areas in terms of lost ecological functions, reduced or lost production, increased run-off and dust hazard, such areas are delineated and mapped.

Elsewhere, in less severely affected areas, more appropriate and controlled use of the rangelands appears to be encouraging the processes of natural recovery.



Range surveys started and completed in Western Australia.



Range condition in arid areas relates primarily to the long-term status of perennial plants and soil surfaces, not to transient appearances of seasonal herbage and availability of feed at the time of the survey. These photos were taken two months apart, the top one in June 1986, the other in August.

Table 1. Range condition classes for five surveyed areas

Region	Percentage of traverse assessments in each range condition class: good	fair	poor	Total area (sq. km)
Murchison	21	37	42	83,000
Gascoyne (1970)	32	53	15	63,400
West Kimberley (1972)	20	50	30	89,600
Nullarbor (1974)	50	10	40	47,400
Ashburton (1976-78)	64	27	9	61,200
Carnarvon Basin (1980-82)	45	32	23	74,500
Percentage of areas combined	36	37	27	419,100

Rangeland monitoring

Many survey sites in good condition show no obvious signs of decline of the rangeland. Some sites in poor condition show signs of recovery, others a continuing decline. The techniques of assessing long-term changes by rangeland monitoring will confirm or deny the persistence of such trends, which a once-only survey cannot properly address.

A rangeland survey establishes a baseline of geographical information upon which land use and appropriate management can be planned. To make this possible, the survey must identify the characteristics of beneficial changes or those changes likely to cause degradation in each type of land unit throughout the region.

Rangeland monitoring will detect changes and long-term trends in the soils and vegetation, and interpret these changes. The vastness and variability of soils and vegetation on pastoral leases dictates that monitoring schemes being operated jointly by station managers and Department of Agriculture staff must be planned strategically, using the information and insights provided by regional surveys.

Evaluating grazing potential and land condition by land systems

The concept of mapping land systems was first developed in Australia to classify and map rangelands on a small scale (1:250,000 or 1:500,000) over extensive areas. Although technological innovations such as satellite images and computerized map bases are now common-place in preparing such maps, the basic concept has withstood the test of time.

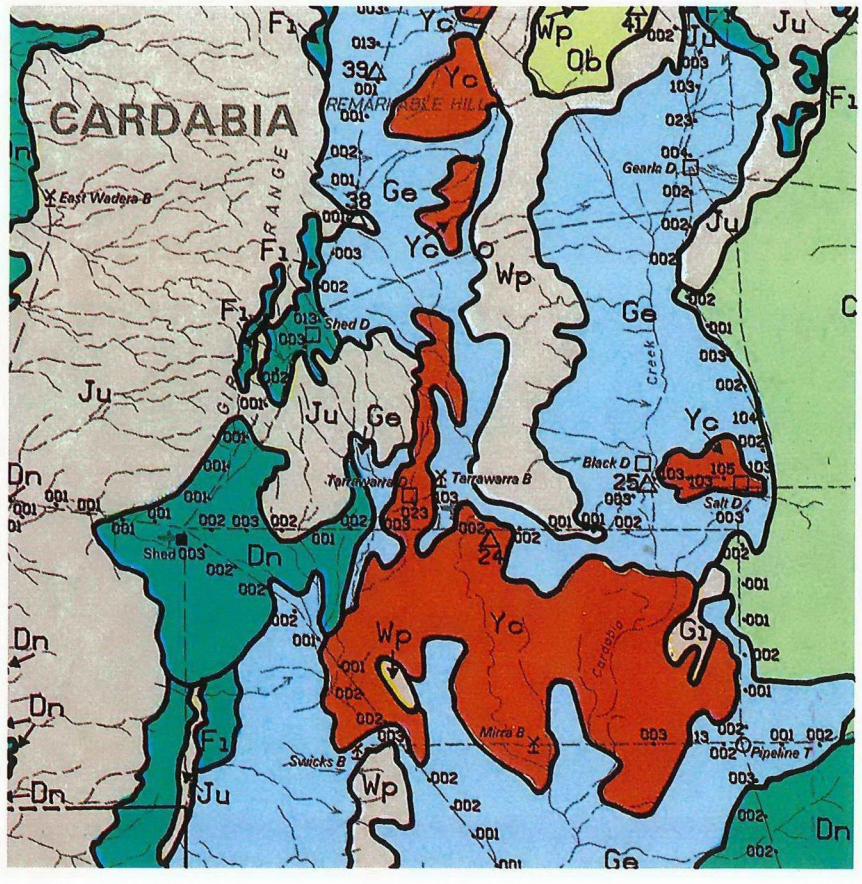
A 'land system' is an area, or group of areas, throughout which there is a recurring pattern of topography, soils and vegetation.(Map 2 here)

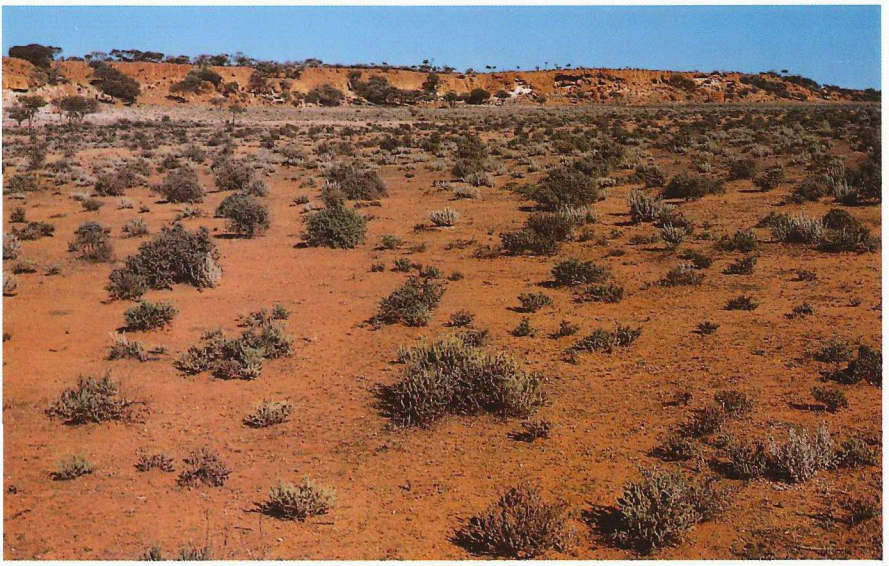
Each land system is made up of 'land units'. These land units, with their varied drainage characteristics, soils and vegetation, occupy different parts of the topography. They often respond to grazing and other management practices in different ways. A land system will often include one or more land units which are particularly vulnerable or sensitive to management practices. Once these various land units have been identified, the overall success of a land management scheme can generally be assessed from its effects on key land units.

Systematic coverage

During each survey, rangeland survey teams compile essential data for each land system by sampling at inventory sites. These sites are specially selected for their representative features which need to be recorded so that each part of a landscape can be characterized. The sites are repeated within each major land unit throughout its variations found across a region. In this way, patterns of landform, drainage, soils and vegetation emerge within tracts of country surveyed. Land systems can be defined, indenitifed and mapped on stereoscopic aerial photographs.

Maps of land systems and colour-coded pasture types prepared by the Department of Land Administration show the grazing resources of a station as simply as possible. By knowing the extent and key features of each type of land on the station, a pastoralist can plan the grazing use and management appropriate for each area of rangeland.





The framework of resource inventory is then used to assess the condition of the land. Condition relates to the cumulative impact of pastoral use and management. Knowledge of the land's condition is important, both for matching grazing use to land capability and for devising management objectives appropriate for a particular paddock or area of interest. The condition of soil surfaces and vegetation are assessed across each type of rangeland.

Observations are made at one-kilometre intervals during vehicle traverses. Traverse ratings are calibrated against objective measurements of composition of vegetation and soil stability taken at 'condition sites' selected within the major land units. Condition sites are established at pre-selected locations to record the status of soils and vegetation on major, well-known land units and to highlight the differences between such country in good, fair or poor condition when grazed.

Condition sites are also being used to test popular hypotheses about variations in the condition of land and vegetation within the 20 to 100 sq. km paddocks common in the rangelands. For example, sheep often graze into the wind. Does the upwind side or quadrant of a paddock lose its condition more than other sectors of the paddock? How different are such effects in various types of country? How far apart can watering points be sited without restricting the grazing radius of stock and causing the development of range condition gradients (variable patterns of grazing impact) within the paddock?

Surveys also provide new information on the exact locations of fences, stock watering points and other station developments that can be accurately depicted on updated station plans. It is now possible to produce station plans and other thematic maps (such as of erosion hazards for mining exploration) at a range of scales to suit users' needs because all of the survey's information that can be mapped is stored in a geographical information system.

Footslopes below lateritic breakaways in the upper Murchison originally supported stands of palatable perennial saltbushes and bluebushes which have been widely over-grazed by sheep, feral goats and kangaroos. Conserving or reclaiming this vegetation and soft soils poses special problems for management of the paddock.

Top: Areas where low shrub vegetation and soil surfaces are in very good condition are now rare.

Middle: Shrub cover is patchy, plant composition is degraded and bare areas are eroding.

Lower: Shrubs are almost eliminated and the whole soil surface is eroding by sheeting and micro-terracing.

Native perennials, soil conservation and grazing management

Recent fieldwork in the Murchison catchment south and west of Meekatharra has shown that young perennial plants have re-established naturally over wide areas within vegetation that has been degraded to a varying extent.

On some types of soil, such as the red earthy sands of wanderrie banks and sand plains, or shallow gradational calcareous soils of major watercourses, key perennials include several genera of native grasses such as *Eragrostis, Monachather, Enneapogon* and *Thryidolepis.* Otherwise, shrubs and perennials herbs are the mainstay of the region. Shrubs of the chenopod family, often found only as understorey vegetation in mulga country, are frequently key species in the recovery of such rangeland.

Fruits of Murchison mint bush, Eichlerago tysoniana, a palatable perennial collected previously only in the 1890s at one locality. It is now known to exist at many sites where Permian rocks meet sandplains in the far west of the Murchison survey area.

Chenopod shrubs are an important source of browse for stock during dry years. The shrubs also preserve otherwise erosion-prone soil surfaces on many of the more productive land units, such as tributary drainage plains and alluvial footslopes. By correctly managing these natural events in re-vegetation through conservative stocking and by tactically seasonal (rather than perpetual) use of paddocks, such rare events in the regeneration of quality browse species can be coaxed along and transformed into long term gains in pasture condition and soil conservation.

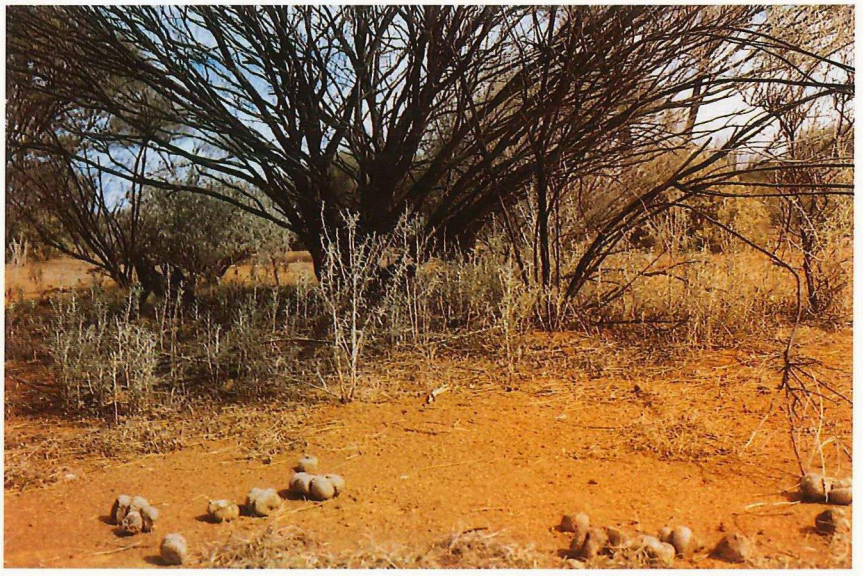
Discovering new species of shrubs

A wide variety of native plants contributes to pastoral production in the winter rainfall areas of the pastoral zone. Many of the not so widespread species are little known, either botanically or in terms of their responses to grazing management practices.

Rangeland surveys have added considerably to our knowledge of the geographical range, abundance and occurrence of such species in relation to basic characteristics of land form, soil type and associated vegetation. Several species new to science have been discovered through the survey programme, while other 'lost' plants have been found again.

Reporting the essential information for long term use

Technical reports from regional surveys now cover a much wider range of resource features than previously. Subjects in the final report include climatic patterns, groundwater resources and vertebrate pests, all in recognition of their importance to pastoral management.



A mass of very young mulga bluebushes, Maireana convexa, regenerating under grazing by sheep and donkeys. Once established, valuable browse shrubs can live for many years.

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Monitoring Western Australia's rangelands

By **Ron Hacker**[1], **David Beurle**[2] and **George Gardiner**[3]

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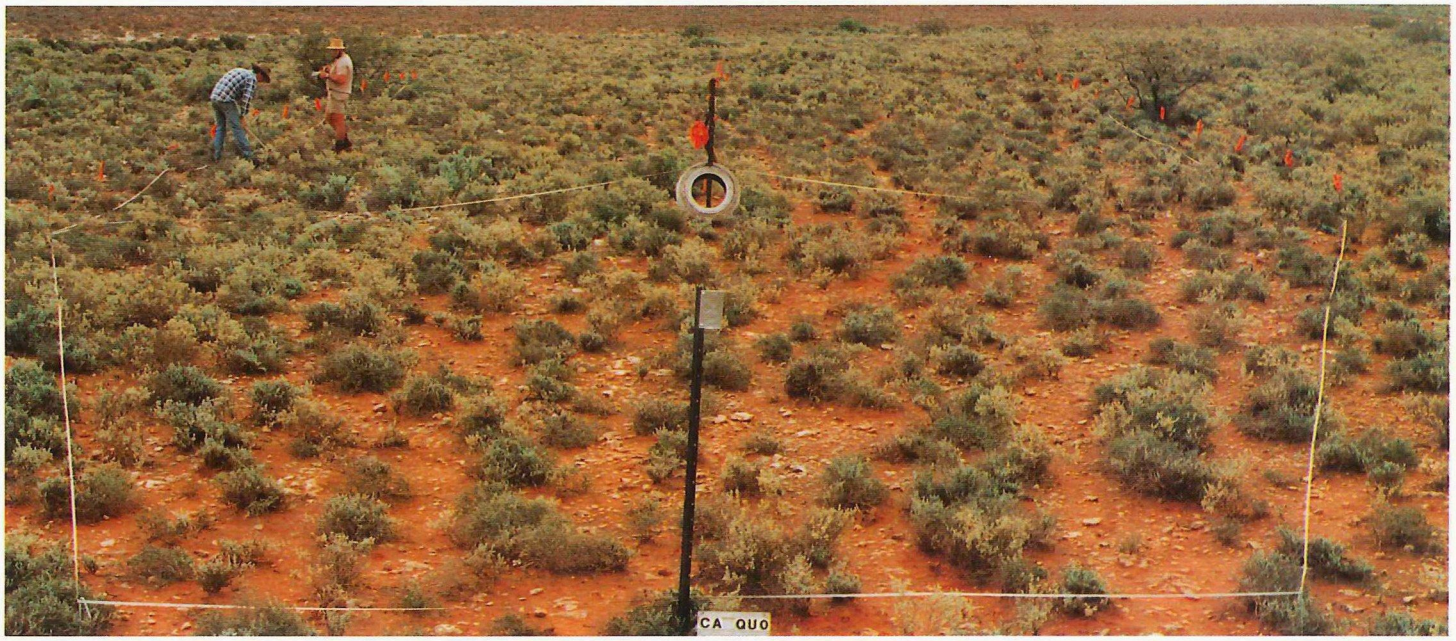
Rangelands, native pastures used for grazing domestic livestock, occupy about 100 million hectares or 40 per cent of Western Australia, extending from the tropical grasslands of the Kimberley to the arid shrub steppe of the Nullarbor Plain.

These areas support about 2.5 million sheep and 850,000 cattle, 8 and 49 per cent respectively of the State totals.

The rangelands are characterized by highly variable seasonal conditions. Carrying capacity can fluctuate dramatically from year to year. Grazing management requires a tactical approach from one season to the next because of the great variation in the capacity of the land to support stock. In such uncertain environments pastoralists must aim to maintain the palatable perennial pasture species which are essential for relatively stable animal production. Managers need to observe the effects of grazing on pastures and soil and vary stocking rates and stock distribution accordingly.

Rangeland monitoring provides pastoralists with objective information on these changes to assist their management decision making. The Western Australian Rangeland Monitoring System (WARMS) is being developed for this purpose.

Rangeland monitoring programmes can also provide land management agencies with information concerning long term changes in the State's land resources. This information will help foster a viable pastoral industry consistent with the wider objectives of conservation and sustainable land use.



Monitoring site in the winter rainfall shrublands. The tape defines the boundary of the photo site. Vegetation data will be collected from the area behind the photo site. The tyre assists in site relocation.

This photo was taken on Quobba Station near Carnarvon.

Designing a monitoring system

Rangeland monitoring systems are generally based on the assumption that changes observed on carefully selected sites or "key areas" can be used to assess management effects over larger areas.

Effective monitoring systems should provide pastoralists with readily understandable data on changes in vegetation and soil conditions, and also some method of interpreting what caused these changes. These causes, and their relative importance, cannot be precisely identified, but they need to be assessed to determine whether observed changes are likely to involve grazing effects or are merely the result of seasonal variations. In addition, monitoring sites should provide useful information for management even when varied pasture types occur within the one paddock or management unit.

The latter requirement can most easily be met when monitoring sites are installed following the completion of regional rangeland surveys,

although this is not essential. Knowledge of the pasture types occurring within each paddock, and estimates of their potential carrying capacity, allows monitoring sites to be located in the areas which contribute most to potential pastoral productivity, and towards which management should generally be directed. Site selection combines such information with the accumulated experience of pastoralists to ensure that local anomalies in grazing distribution are avoided, and that areas of special management interest are identified.

Interpretations of the relative importance of grazing and seasonal or environmental factors in producing the changes observed at monitoring sites will always be difficult. However the establishment of sites in "reference areas" on each lease, where grazing pressure is known to be light because of distance from water or other factors, and in fenced "bench-marks" established on a regional basis, can provide comparisons from which informed judgements can be made.

Historical developments

The need to develop methods for rapidly collecting information on changes in perennial plant populations and soil conditions, over large areas, has long been recognized by rangeland advisers.

Large scale aerial photography

In the late 1960s the use of large scale aerial photography appeared to offer much promise for this purpose.

In 1970, the Western Australian Department of Agriculture, in conjunction with the Rangelands Research Unit of CSIRO, undertook the first Australian assessment of such photography for rangeland monitoring. This study indicated that large scale (1:200) colour or colour infra-red photographs were an ideal base for mapping and recording of individual plant species in a range of vegetation types. Acceptable estimates of plant cover could also be made and the condition of the soil surface was clearly recognizable, particularly on colour infra-red film.

However neither film type permitted highly accurate identification of all species examined. Furthermore, for best interpretation, photographs needed to be taken within four to six weeks of effective rain and some plants growing beneath tree canopies were obscured by foliage or shadow.

Nevertheless, the results of this investigation were generally encouraging. In the following years over 100 "flight lines" were established on pastoral leases, particularly where existing exclosures enabled nearby grazed and ungrazed areas to be photographed, and in paddocks in which other research programmes were in progress.

Large scale aerial photography has proved to be an excellent research tool in studies which require data on changes in plant populations or the spatial arrangement of plants. However, it soon became evident that the task of establishing permanently marked flight lines, the cost of acquiring and printing the photographs, and the labour requirements for "marking-up" in the field (since plant species could not be identified accurately from the photographs alone), would preclude the use of the technique for an extensive monitoring programme.

Development of alternative methods subsequently proceeded along two lines.

Photo points

Photographic records of permanently located sites, obtained with a hand-held camera from an elevated position such as the roof of a vehicle, proved to be a simple, rapid and cost-efficient procedure.

Several hundred of these "photo-points" were established, particularly in the East Gascoyne, Murchison and Goldfields areas, and standardized procedures for delineation of the "photo-plot" and recording of plant populations on photo-overlays were developed. The major limitation of this technique was the small area that could be included in the field of view, although the method did provide for general landscape photographs to be taken, in a standardized fashion, simultaneously with the "close up" plot photograph. Another limitation was the lack of any provision for adequately describing the condition of the soil surface.

"Plotless" sampling

The second line of approach involved attempts to measure plant density over larger sample areas, and to provide more definitive information on the condition of the soil surface. The "plotless" sampling method used to determine plant density proved unreliable in most situations and this approach was never implemented as a practical procedure. However, the definitions developed for the rating of soil surface condition in terms of the type, intensity and extent of accelerated soil erosion proved reasonably workable. Operators could at least rank the soil condition of a site, based on defined criteria.

The WARMS technique for arid shrublands

The WARMS technique now used in the shrublands south of Kimberley combines the most desirable features of the earlier approaches with additional soil and vegetation data.

Monitoring sites (Figure 1) usually consist of a photographed area or "photo-plot" to provide a permanent visual record of change, and a series of fixed "belt" transects within which shrubs are individually recorded in terms of species, and canopy width and height.

Species which cannot be readily measured because of their growth habit are counted. These data are recorded within subsections of the transects called blocks. This allows overall changes in the total population of a species, or group of species, to be understood in terms of gains and losses within individual blocks. The density of shrub seedlings, and of herbage and grass species, is scored on an interval scale. Plant counts within the photographed area supplement data from the larger area sampled by the transects.

Soil surface condition is assessed on quadrats located at regular intervals between the transects. The erosion status of the site overall is rated by using the scale and definitions discussed previously.

This method has been adopted as the standard procedure for monitoring sites in the shrublands, except in some degraded situations where low plant density does not justify the recording of detailed vegetation data. In these situations, soil condition is assessed in the usual way, but vegetation recording is restricted to the photo-site. The photographic record itself provides the most useful assessment of change in these circumstances.

The same procedure is used on "reference sites" located in areas of low grazing pressure. These sites, together with fenced bench-marks, will provide comparative data to assist with interpretation of the likely causes of the observed changes in the vegetation. At the bench-marks, more detailed and more frequent data, recorded both inside and outside the fenced area, will add to the understanding of vegetation changes in relation to both grazing and seasonal conditions. This information will assist with the development of management strategies designed to foster or ameliorate changes observed at monitoring sites.

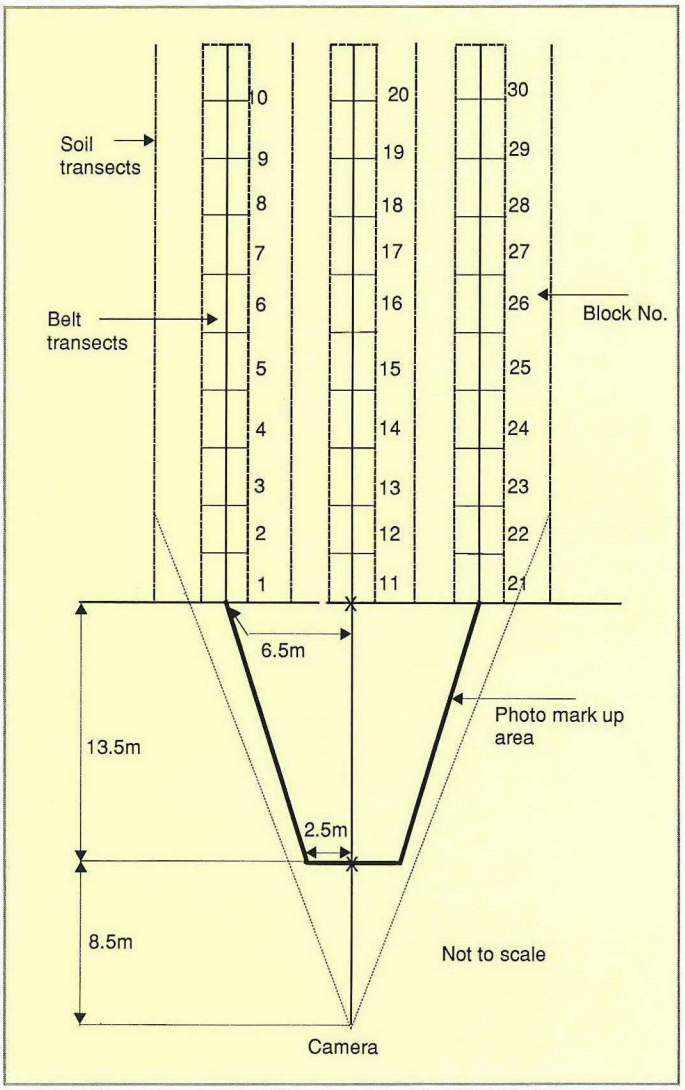
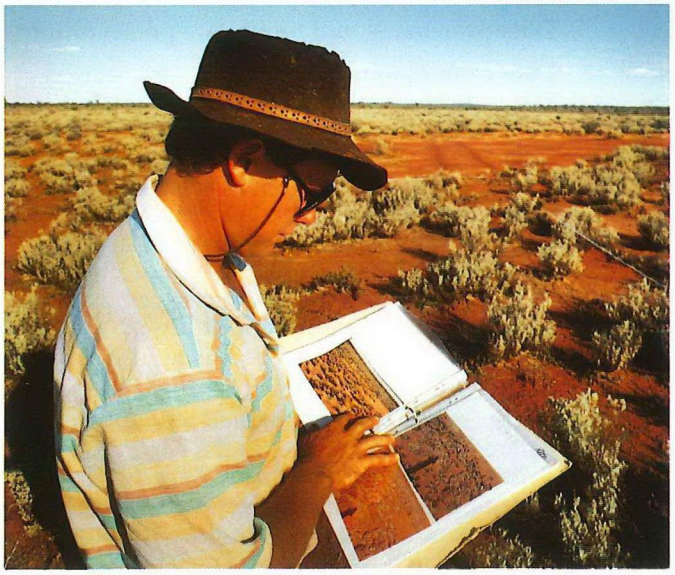


Figure 1. Layout of a typical WARMS monitoring site in the southern shrublands.



Tony Crook of Woolabah Station checks changes in vegetation on a monitoring site against photographic records.

Field procedures

The site installation and data collection procedures of the WARMS system have been developed into a rapid and efficient technique.

After selecting the site location, the photo-plot and transects are permanently marked with galvanized pegs and steel pickets for ease of relocation at subsequent assessments.

Four main types of data are collected at each site.

Site description details. These are recorded on a standardized Site Information Sheet and include the site identification code, land system and pasture type, location description, aerial photo reference, map grid co-ordinates and recording specifications.

Photo-plot information. Plant counts within the photo-plot are recorded on a proforma which includes provision for coding and description of unknown species.

Three photographs are taken. These include a colour slide for long term storage, a colour print for enlargement and presentation in the station monitoring file, and a polaroid print on which plant species in the photo-plot are identified in the field for later transfer to an overlay on the enlarged print.

Soil surface condition information. The results of quadrat sampling for soil surface condition and the overall site erosion rating are recorded on the Site Information Sheet.

Vegetation transect information. All vegetation recordings on the transects are entered on a portable computer in coded form. These data are unloaded onto cassette tape in the field as each site is completed.

Data processing and report file presentation

Data from monitoring sites are summarized and returned to the pastoralist as a station monitoring file. The file is designed to allow pastoralists to observe their sites for any changes that may occur between assessments by Department of Agriculture staff. Observation of these changes (for example establishment of new plants or loss of part of the original population) allows management to respond at the earliest opportunity.

Data processing

When field work is completed all data are entered onto a computer at the Department's district office. These data are decoded, edited and summarized during preparation of the station monitoring file. The data are subsequently stored in a central data base so that comparisons can be made with previous or later recordings.

Monitoring file presentation

Site photographs are the focal point of the monitoring file because they help pastoralists regularly assess changes in plant populations. Each photograph is accompanied by an overlay prepared from the field polaroid which allows pastoralists to identify the important species present on each site. Summarized vegetation data from the transects are also presented, which indicate the population present at the start of the inventory programme, and changes observed since the last recording.

Implications for production of any changes noted on the sites are noted in the file, together with suggestions regarding the management options available for maintenance or improvement of the pasture resource.

These files are laminated and durable so they can withstand regular paddock use. When the completed file is returned to the pastoralist, rangeland advisers discuss observed changes in the rangeland and their implications with the pastoralist in relation to the management of the whole property.

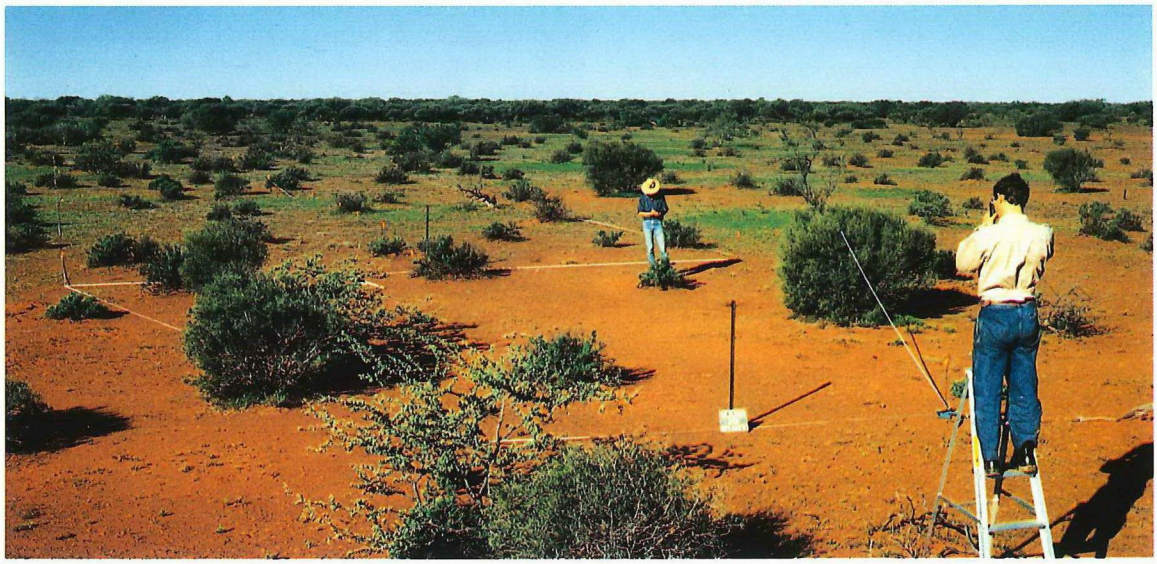
Development of monitoring coverage

Rangeland monitoring has been enthusiastically embraced by many pastoralists; an indication of the growing trend towards conservative management systems in the rangelands. Installation of site networks has been particularly active in the West Gascoyne and Murchison where project teams supported by the National Soil Conservation Program (NSCP) have operated for the past five years.

Over 2,000 monitoring sites of various types have now been established in the rangelands. Progressive implementation of site networks, based primarily on requests from pastoralists, will see the coverage gradually extend throughout the pastoral areas. Eventually, the total network will probably exceed 10,000 sites.

The expansion of the monitoring programme has been made easier by the establishment of Land Conservation Districts. Eleven districts have been gazetted in the pastoral areas, and these, together with other districts being formed, will cover almost all of the rangelands.

The formation of Land Conservation Districts allows rangeland management to be tackled on a regional basis. Monitoring sites can be established as part of the development of large scale catchment management programmes which incorporate management plans for individual stations. Such a programme is



Photographic records form a vital part of the monitoring system and provide a visual representation of measured changes.

being undertaken in the Murchison River catchment, an area of about 60,000 sq. km, with support from the NSCP.

Continuing developments

Although monitoring site networks of the type described will provide useful information for both pastoralists and land administrators, the number of sites which can be established and maintained is limited by the staff available. At present, sites are being established at an average density of about one per 7,500 ha. A capacity to assess changes in the landscape overall would complement information collected from these sites. Work is proceeding on the evaluation of satellite (LANDSAT) imagery as a means of providing this overview.

Images from two dates, when processed to indicate the "brightness" or reflectance of the land surface, can be used to generate an image which depicts the pattern of change in landscape brightness between the two times of observation. These changes are influenced by grazing and seasonal conditions and particular patterns of change are represented by specific colours.

When such images are interpreted in conjunction with local knowledge of paddock stocking histories, seasonal conditions and trends in vegetation and soil conditions observed at monitoring sites, a much more complete picture can be built up. Such interpretations are made easier by the ability to overlay, using computer graphics techniques, the location of monitoring sites, fence lines, watering points and vegetation types on the processed LANDSAT imagery.

Pastoralists and advisers interpreting these combined images will be able to extrapolate trends from monitoring sites to larger areas with greater confidence, or alternatively detect areas where changes appear but where monitoring sites are not located. These areas can then be assessed in the field and additional sites installed if necessary.

To produce such combined images, large amounts of map data in digital or computer compatible form are required. All 1:250,000 scale maps of rangeland resources produced by the Department of Agriculture's rangeland survey programme have now been digitized and complete coverage will be built up as further surveys are completed.

Pastoral lease boundaries and property development details (for example fence lines and water points) are being digitized for all leases in the State in on-going programmes conducted by the Departments of Land Administration and Agriculture. Cost may prevent the routine production of these images but at least the capacity to produce them when needed is available.

Although monitoring procedures are well established in the shrublands south of Kimberley, techniques are still being developed for the northern grasslands. In response to a request from the pastoral industry and with the support of Cattle Industry Compensation Act funds, the Department of Agriculture has investigated a range of potential methods at Gogo Station. It was expected that the grasslands, with their denser plant populations, frequent fires and rapid growth responses to annual rain, would require different methods to the shrublands further south.

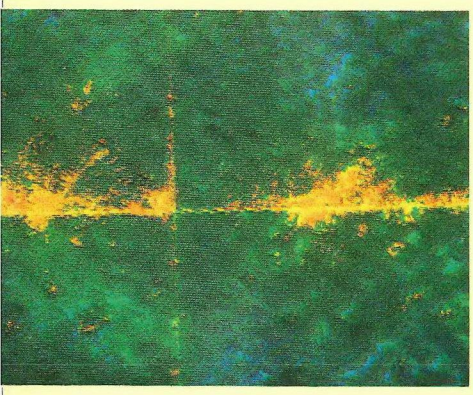
LANDSAT IMAGES

Two examples of the patterns of change in the "brightness" or reflectance of the landscape on a Nullarbor pastoral lease. The top image has been produced from LANDSAT data acquired in September 1982 and September 1985 while the other was produced from data acquired in September 1982 and September 1986.

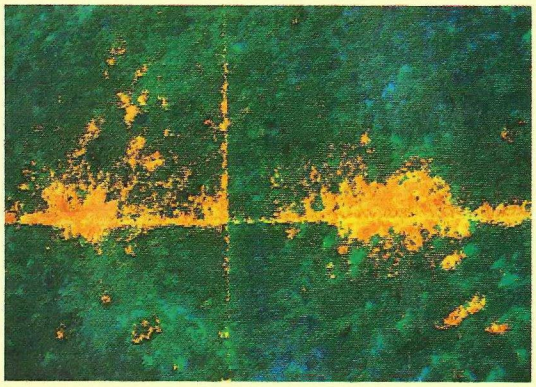
In both cases the red tones indicate areas where landscape brightness was low in 1982 but increased up to the time of the second observation. Green tones indicate little change in landscape brightness.

The red areas are associated with grazing activity in the vicinity of sheep watering points, leading to an increase in brightness probably associated with changes in soil surface characteristics. The expansion in the area affected between 1985 and 1986 is evident from a comparison of the two images.

Red tones do not necessarily indicate overgrazing as evidenced by the red tones also visible along fence line tracks. However such imagery, when interpreted in conjunction with changes observed at ground sites, can help define the likely extent of changes measured on the ground, or identify areas where atypical changes should be inspected in the field.



LANDSAT data from September 1982 and September 1985.



LANDSAT data from September 1982 and September 1986.

As with the southern methods a network of ground-sites will be established, one or two in each management unit (paddock or water point vicinity). These sites will be readily accessible to pastoralists and will need to be visited regularly if they are to provide the most benefit to management.

Methods that show promise for these sites include oblique photographs of fixed areas (a feature included in the shrubland method) and plant mapping within permanently marked areas using photographs obtained by a vertically suspended camera. Estimation of the amount and species composition of forage available at a site in terms of biomass has proved difficult and the detection of grazing effects using this approach may be unreliable, especially given the staff changes to be expected in a long term monitoring programme.

An alternative being investigated is to group sites into a number of classes based on total basal cover (assessed relative to the potential of the site rather than in absolute terms) and the proportion of desirable species present.

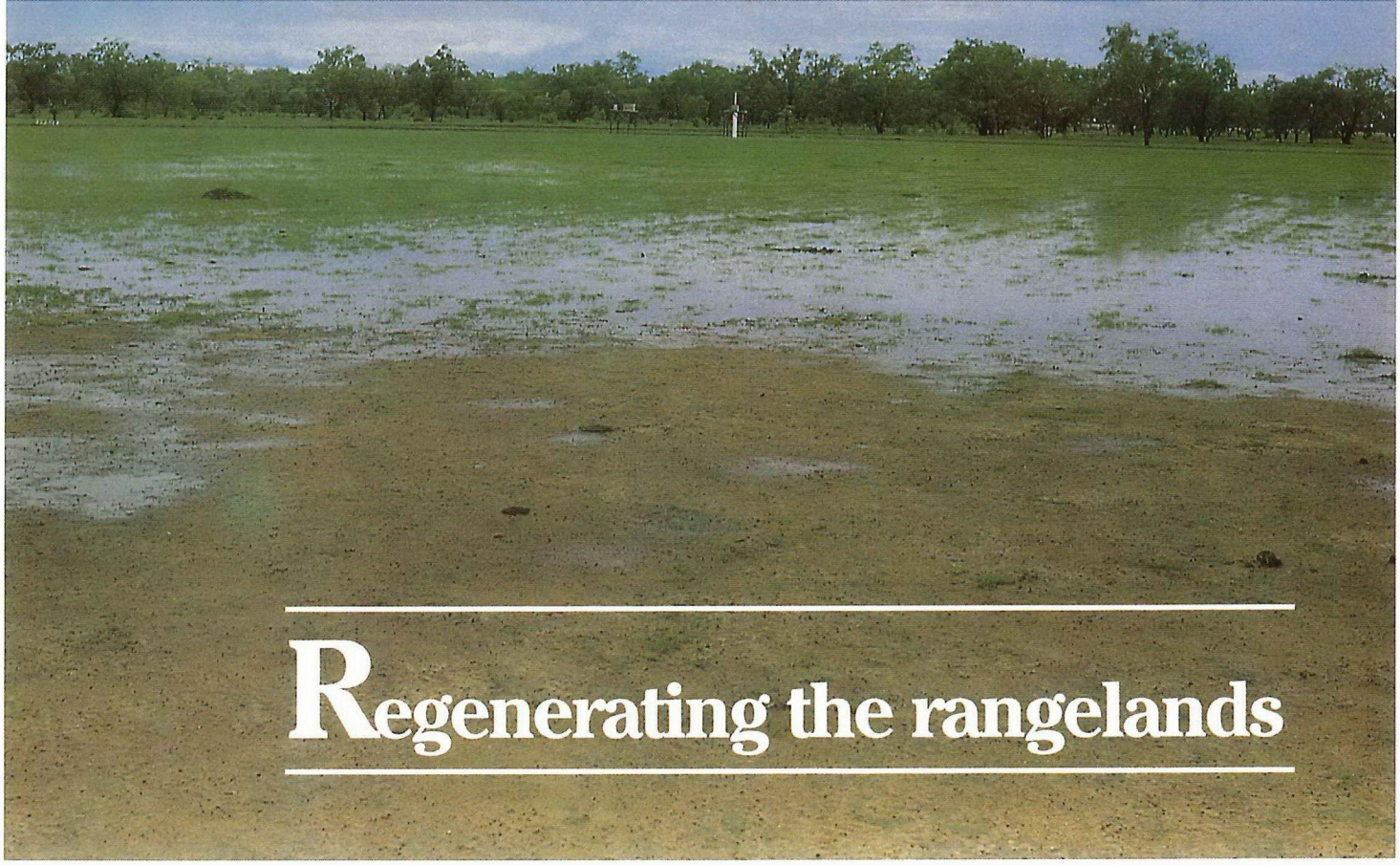
Sufficient results will be available to allow the development of an operational method by late 1990 so that existing sites can be upgraded to provide a reliable monitoring service for the Kimberley pastoral industry. The frequency with which sites are recorded will need to be greater than for southern areas as changes in these grasslands can be rapid and dramatic.

Overall benefits

Pastoralists, land administrators and rangeland management advisers all benefit from the collection and analysis of information on changes in range condition.

The Western Australian rangeland monitoring system has been designed primarily to provide information which can assist pastoralsits with practical grazing management decisions. In the medium term this information will be derived from data collected by Department of Agriculture advisers, but more frequent observation of sites by pastoralists themselves will provide the most important information for short term decision-making.

Data collected by the monitoring programme will improve advisers' understanding of the processes of change in rangeland environments thus enhancing their ability to recommend appropriate management responses. At the same time data on changes in range condition can assist with the decision-making of land administrators. It can provide the community with objective evidence that pastoral land use need not be incompatible with broader conservation objectives in the rangelands.



Regenerating the rangelands

By **Adrian Williams**, Adviser, Department of Agriculture, Kalgoorlie, and **Ron Shepherd**[1], District Manager, Department of Conservation and Land Management, Denham

Parts of Western Australia's rangelands have been degraded by inappropriately high stocking rates, often associated with large numbers of native or feral animals, poor seasonal plant growth, or the ravages of cyclones, floods or fire.

Today, most pastoralists are keen to rehabilitate the degradation of the past, as indicated by the proliferation of Land Conservation Districts (LCDs) throughout the pastoral zones.

The first activity of many new LCDs has been to start a regeneration cultivation programme. The results have often been disappointing because of poorer plant growth than anticipated for the money spent.

For best results, rangeland regeneration activities need to be part of the management priorities for the whole station, and be incorporated into the management plan. For example, destocking one part of the station for regeneration purposes could lead to over-stocking and degradation on other areas if stock numbers remained the same.

There is no 'quick fix' to regenerating the rangelands. It may take many years to achieve the desired result.

[1] Formerly Rangeland Management Adviser, Department of Agriculture.

Stocking rates

A station's first range management priority should be to ensure that all productive land is stocked at an appropriate rate for the particular soil type, the seasonal conditions and the current range condition. Grazing of severely degraded areas should be avoided.

Only then should a pastoralist consider the timing and implementation of a regeneration programme involving costly cultivations and seeding.

Planning for successful regeneration

The successful regeneration of an area of rangeland requires the following:

- Control of all grazing animals.
- Adequate available soil moisture for plant germination and establishment.
- Suitable 'niches' on the soil surface in which seed can lodge, germinate and establish.
- A suitable seeding technique.
- A seed source of rangeland plant species adapted to the area.
- Adequate soil fertility to promote the establishment of plants.
- Adequate finance to carry out the planned regeneration programme, and to maintain fences and cultivations.
- The installation of monitoring sites to assess the rate of plant recovery, and the timing, and intensity of re-grazing the area.

Information should be collected on these requirements during the planning of a regeneration programme so that the most appropriate techniques can be used.

The striking effect of water ponding on a West Kimberley site. The pond bank is near the trees.

The extent of water ponding is clearly seen by the surface water and the grass growth in this photograph taken early in the wet season.

Water ponding and cultivation trial site in the Carnarvon area. The tractor indicates the size of these motorgrader-built ponding banks.

An aerial photograph of extensive pitting and chisel plough cultivation on the Fitzroy River frontage.

Control of grazing animals

Grazing must be controlled to allow established plants to seed, and new plants to establish and produce more seed. Grazing of sheep and cattle can be controlled by fences, the positioning of water-points, or both. Such control is not usually a problem.

Goats, donkeys, camels and rabbits are more difficult to control. They are a serious problem for regeneration programmes. In some LCDs, monitoring of kangaroos by sampling dung weight indicated that the kangaroo population was similar to the combined population of sheep and feral goats.

Grazing control on an area to be regenerated will be most effective, given present technology, by:

- closing down watering points in and around the regeneration area, and fencing off natural waters; and
- controlling vermin and culling kangaroos as permitted under the quota system.

Control of grazing animals may be all that is needed in some areas, or all that is possible.

The key to management for regeneration is to destock the affected area during periods of active plant growth and seed production, and to lightly stock the area, when possible, at other times to ensure that ground cover increases year by year. Initially, the ground cover remaining after grazing may be no more than a dead mulch layer, particularly in annual grasslands. However, this mulch layer reduces erosion, traps wind-borne material, conserves soil moisture, reduces soil temperature, and promotes the establishment of perennial plants.

Providing adequate soil moisture

There are many techniques to trap and use rain and run-off water to provide enough soil water for rangeland regeneration. They can be broadly described as: land shaping; cultivation; and soil amelioration.

Land shaping

Land shaping involves building earthworks to divert, harvest or spread run-off water. The type of structure used will depend on the particular regeneration problem. All these forms of structure may need to handle large volumes of run-off water and must be properly planned, surveyed and constructed.

Embankments

Embankments at the heads of gullies are the most common form of water diversion structure used in rangelands. Embankments divert water away from the gully head and 'starve' the gully of the water it needs to cause further elongation. They can divert run-off water to surrounding areas, thereby improving soil moisture status.

On land with an appreciable slope diversion banks must be used with care so as not to cause secondary gullying. The discharge should be directed into water-spreading structures which release the water as a broad, shallow flow. Water-spreading structures can be used alone to stop the formation of minor channelling of run-off on slight to moderate slopes.

Gully head embankments and water-spreading structures are usually constructed by bulldozers or road graders. They are expensive, and are usually only considered economical where erosion is putting buildings, fences, roads and other infrastructure at risk, or where the earthworks will have a beneficial effect over a large area.

Water ponding

Water harvesting, or 'water ponding', retains rainfall or run-off water behind banks built with a bulldozer, road grader, or tractor-drawn opposed disc machine.

Water ponding can be used on gently sloping land (up to 0.3 to 0.4 per cent slope) to cause the formation of a series of shallow lakes after rain, thus increasing the opportunity for water to infiltrate into the soil. Results from a trial in the Carnarvon area showed that water ponding increased soil moisture after rain by up to 56 per cent.

Individual water ponds cover about 0.5 to 2 ha, depending on ground slope and site. On slopes of less than 0.1 per cent full-circle ponds can be constructed which will contain direct rainfall only; on slopes up to 0.4 per cent open-ended, horseshoe-shaped banks can be built to catch direct rainfall and a proportion of the run-off flowing across the area.

Banks should be surveyed carefully and built to ensure that water is held no deeper than six centimetres in the pond, and that excess water will spill around the end of the banks. Deeper water may cause breaching of the bank.

Water ponding layouts are not suitable for areas subject to deep flooding, unless resources are available to rebuild the banks after flood damage. In areas where intense run-off is expected, water ponding layouts should start as near to the top of the catchment as possible. Layouts should avoid harvesting water from flowlines because this invariably leads to failure of ponding banks.

Water ponding can cause rapid leaching of salts from saline surface soils, thus improving conditions for plant establishment. On soils which generally set hard when dry and 'slake' when wet water ponding tends to increase soil cracking as the soil dries, which aids regeneration. The cracks trap wind-borne seed, and increase infiltration during the next rain.

Cultivation

Cultivation for regeneration purposes increases the availability of soil moisture to plants and provides a suitable bed for seed to lodge and germinate, and for plants to establish. Four main types of implement are used in regeneration work: rippers; ploughs; pitters; and bank builders or 'hillers'.

All machines produce their best results when used on the contour, because this maximises run-off interception and minimises the risk of erosion as a result of the cultivation. At the start of cultivation a few reference contour lines should be surveyed and marked on the ground with the cultivation implement. Subsequent cultivation should run parallel to these contour lines.

Cultivation by the Mallen Niche Seeder, showing favourable saltbush establishment two years after sowing.

Rippers

Rippers loosen compacted soil and increase its moisture holding capacity to depths of up to 50 cm by breaking and lifting the soil, all of which encourages the survival of establishing perennial plants.

Rippers work best in deep soils free of stones and roots. They should be fitted with shear-pins or stump-jump facilities to protect the implement, tractor, and operator.

There are disadvantages from using rippers: they have the highest horsepower requirement per metre width of cultivation of all cultivation implements; and they may not create particularly favourable niches for seed germination. Recent developments in ripper design have produced rippers requiring less horsepower. Low-draught rippers are a particularly useful primary cultivation tool when followed by pitters or hillers.

Ploughs

Chisel ploughs are usually used for regeneration cultivations. Disc and mouldboard ploughs tend to create a sheared, smeared layer in already compacted soil. Chisel ploughs are particularly effective where a compacted, sealed soil surface crust is the main soil constraint to plant establishment.

This protected river saltbush (Atriplex amnicola) *is a prolific seed producer. It was sown with a Mallen Niche Seeder in a water pond in a paddock containing no sheep.*

The mesh guard protects the plant from grazing kangaroos and goats to ensure it produces seed for further natural regeneration.

Chisel ploughs cultivate to a depth of 15 to 20 cm. They use less horsepower than rippers. They tend to leave micro-ridges and furrows on the soil surface, thus providing a range of niches for seed to lodge and germinate.

Pitters

Pitters can be disc or tined implements. They produce a series of discontinuous basins or pits commonly 15 to 20 cm deep and wide and 0.8 to 1 m. long on the soil surface. Pitter machines used in Western Australia have either four discs or tines, and produce four rows of pits at each pass of the machine.

Pits trap seed and mulch material, and intercept run-off water, making the pitting technique particularly suitable for areas which receive light winter rain. Suitable niches for plant establishment are in the pit and around its lip. However, seed germination and plant establishment can be impaired if water remains in the pit for more than a week.

Disc pitters tend to smear the surface of their pits by the action of the disc, which decreases the infiltration rate of water through the bottom of the pit. These machines are best suited to light textured soils, or where they can be used in combination with rippers working ahead of the discs.

Tine pitters do not suffer so markedly from this problem, and are suited to a wider range of soil types.

Bank builders or 'hillers'

Bank builders or 'hillers' have a pair of inward-facing opposed discs which create an embankment about 30 to 50 cm high and one metre wide. Machine setting and soil conditions govern the size of the bank.

A refinement of this type of machine includes a ripper or rippers positioned ahead of the discs. The ripper(s) loosen the soil, help incorporate the bank with the underlying soil, and improve soil moisture retention in and under the bank.

Banks should always be cultivated along the contour. They are normally cultivated as discontinuous strips overlapping the previous line of cultivation to form a 'brick wall' pattern. This type of cultivation collects run-off water and improves soil moisture levels, particularly when used in conjunction with a chisel plough cultivating parallel to, and immediately upslope of, the banks. On saline soils, salts tend to accumulate in the top of the banks, and the best position for plant establishment appears to be on the sides of the banks where salt levels are minimised.

Mallen Niche Seeder

The Mallen Niche Seeder, developed by the Department of Agriculture, is a refinement of the opposed disc bank builder. It uses a press wheel to create a furrow, into which seed and soil ameliorants are placed, along the top of the bank. The machine was developed to treat salt-affected sites in the State's agricultural areas, but is being tested for its suitability in the rangeland.

Soil amelioration

Certain problem soils may not respond to cultivation and seeding alone. These soils commonly contain high levels of salts, particularly sodium salts. Soils should be tested for salt levels when planning a regeneration programme. The low levels of available soil moisture often associated with saline or sodic soils can be improved with soil ameliorants.

Trials in the West Kimberley showed that perennial grass establishment can be improved through the use of gypsum, grass mulches and polyvinyl alcohol (PVA), a soil stabiliser. The application of gypsum to sodic soil near Carnarvon encouraged perennial shrub establishment in a trial sowing. However, soil ameliorants are expensive. They should only be used for the establishment of small, nucleus areas of parent plants.

Seeding technique

The seeding technique should place the seed at the required rate on that part of the soil surface where it has the best chance of germinating and establishing to a mature plant. This is particularly important when sowing expensive seed.

Precision seeders should be used when sowing uniform, smooth seed. However, most seed sown for regeneration purposes has some characteristic, such as fluffiness or the presence of awns or bracts, which makes it unsuitable for precision seeders. If the seed can be made more uniform and smoother by removing awns and bracts, the cost of this seed treatment will be more than offset by the reduction in the required seed rate, and the improvement in plant establishment.

Irregular shaped seed, or seed which 'bridges' in the seeding mechanism, is usually broadcast. The most common broadcaster used in Western Australia's rangelands is the 'Monto' - type seeder, which comprises a rotating drum driven by a ground-wheel. The drum contains variable sized openings through which the seed escapes as the implement moves forward, and the drum rotates. Kimberley Seeds Pty Ltd have improved the 'Monto' design by catching the seed as it leaves the drum, and directing it to the desired seed niche on the soil. Thus irregular shaped seed can be sown with some precision.

Seeding and cultivation are simultaneous operations, with the seeding mechanism being mounted on the cultivation implement. Cultivation is best when the soil is moist. Seeding will produce the best results soon before the expectation of seasonal rain.

The strategic timing of the regeneration operation is likely to be a trade-off between the ideal timing for cultivation and seeding requirements. Each rangeland environment will have its own best compromise, which will be found by experience. For example, the most effective time for regeneration operations in the southern shrublands appears to be in March and April, before winter rains.

Sources of seed

Generally, perennial species growing naturally in the area will establish the best. Where no suitable species can be found, or its seed readily obtained, several promising species from other areas may need to be tested. In this case, it is unwise to rush into regeneration operations until

Grazing control is essential for rangeland regeneration. There are no sheep on either side of this fence, only kangaroos and goats on the grazed side.

Table 1. Species for use in rangeland regeneration in summer rainfall, sub-tropical grasslands

	Light to medium textured soils		Heavy textured soils			
Species	Saline	Non-saline	Saline	Sodic	Saline-sodic	Non-saline non-sodic
Barley Mitchell *Astrebla pectinata* (N)				*	*	*
Bull Mitchell *A. squarrosa* (N)				F		F
Weeping Mitchell *A. elymoides* (N)				F		F
Beetle grass *Diplachne parviflora* (N)			*		*	
Birdwood *Cenchrus setiger*		*	*	*		*
Gayndah buffel *C. ciliaris*		*		*		*
American buffel *C. ciliaris*		*				
Buffalo clover *Alysicarpus vaginalis*		*				*
Bundle bundle *Dichanthium fecundum* (N)				F		F
Cassia rotundifolia		*				*
Cavalcade *Centrosema pascuorum*		*		F		F
Endeavour stylo *Stylosanthes guyanensis*						*
Fitzroy shrubby stylo *S. scabra*		*				
Seca shrubby stylo *S. scabra*		*				
Verano stylo *S. hamata*		*		*		*
Gamba grass *Andropogon guyanus*		*				*
Kapok bush *Aerva javanica*		*				
Neverfail grass *Eragrostis setifolia*	*				*	
Woollybutt *E. xerophila* (N)				*		
Phasey bean *Macroptilium lathyroides*		*		*		*
Siratro M. atropurpureum		*				*
Phoenix cowpea *Vigna unguiculata* (prev. *sinensis*)		*		*		*
Sabi grass *Urochloa mozambicensis*		*				
Sensitive plant *Neptunia* spp. (N)				F	F	F

(N): native species
F: some observed flood tolerance

Table 2. Species for use in pastoral rangeland regeneration in arid and semi-arid shrublands, predominantly winter rainfall

	Light textured soils		Heavy textured soils	
Species	Saline	Non-saline	Saline	Non-saline
Buffel grass *Cenchrus ciliaris*		*		
Birdwood grass *C. setiger*		*		
River saltbush *Atriplex amnicola*			*F	*F
Bladder saltbush *A. vesicaria*			*	
Silver saltbush *A. bunburyana*			*F	*F
Old man saltbush *A. nummularia*			*	*
Prickly acacia *Acacia victoriae*			*F	*
Cotton bush *Ptilotus obovatus*		*		*
Gascoyne bluebush *Maireana polypterygia*			*	*
Spiny bluebush *M. aphylla*			*F	*F
Sago bush *M. pyramidata*			*	*
Felty bluebush *M. tomentosa*		*		*
Three-winged bluebush *M. triptera*		*		*

F: some observed flood tolerance

species have demonstrated an ability to germinate and establish, and to persist through a range of seasons.

Managers should aim for a mixture of species with varying palatabilities. This will ensure that ground cover is maintained in the future. Tables 1 and 2 provide suggestions for species that might be tested in an adaptation screening trial.

Seed may be bought or collected. Purchased seed must be accompanied by a certificate of the seeds' purity, weed seed content and viability. Seed collected for sale must also be tested and certified. Before ordering seed, seek advice on acceptable germination percentages for the chosen species.

Collectors who harvest seed from rangelands for sale must have a seed collectors license from the Department of Conservation and Land Management. However, lessees do not need a license when collecting seed for on-station use.

Enhancing soil fertility

Fertiliser is seldom applied in rangeland regeneration because of the cost. However, plant establishment on phosphorus deficient soils is improved by the application of superphosphate, as shown by trials with stylos in northern Australia. Fertiliser application for regeneration work is a standard practice only in the rehabilitation of minesites.

Financial considerations

Mechanical regeneration of rangeland is expensive, and is not a 'quick fix' solution to rehabilitating degraded country. It may take many years before restocking can start to recoup the initial financial outlay. The major areas of expense are:

- control of grazing animals,
- seed supplies,
- machinery costs,
- labour costs,
- costs of financing the regeneration operation, and
- opportunity cost of not grazing the regeneration area.

Some financial costs are tax deductible. Managers should consult the Department of Agriculture or their LCD for cost-saving ideas for regeneration works.

Monitoring sites

Monitoring sites should be installed on regeneration areas, whether they are cultivated or simply destocked, to record the rate of improvement and whether the chosen method is working.

Department of Agriculture staff are keen to help in the installation of monitoring sites, and can advise on the size and siting of a rangeland monitoring network.

A useful checklist

- Don't start without a regeneration plan which is incorporated into the whole station management plan.
- Control all grazing animals.
- Collect information on suitable techniques and plant species for your environment.
- Seek advice. Analyse the costs and benefits of different plants. Investigate your eligibility for tax concessions. Consult your LCD, the Department of Agriculture and your accountant. Decide on regeneration techniques.
- Plan a programme in phase with the seasons, which incorporates grazing control, and - if cultivations are to be used - availability of seed and machinery.
- Carry out the programme, and monitor the response.

Further reading

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Station management planning in the rangelands

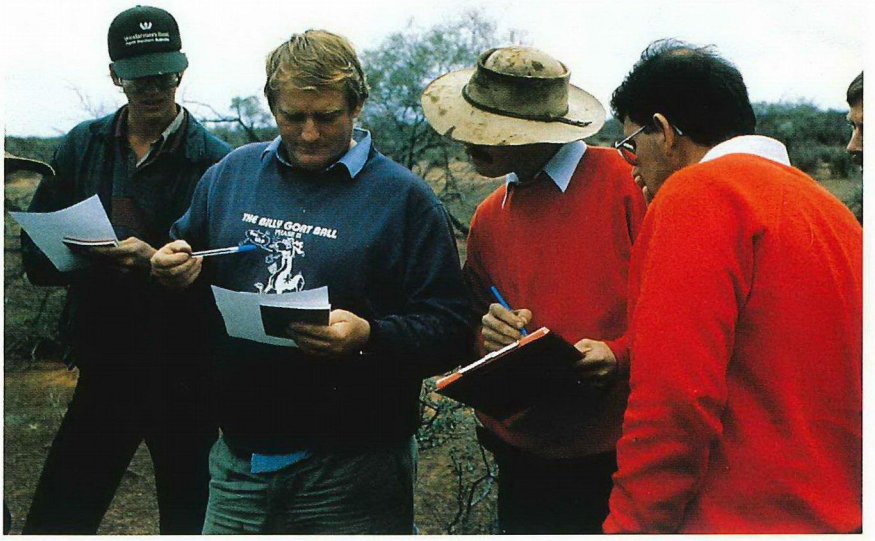
By **John Morrissey**, Principal Adviser and Donald Burnside, Adviser, Rangeland Management Branch, South Perth

Whole station management planning is the best way of moving towards the optimum use of pastoral lands.

The Department of Agriculture is committed to support and guide station managers in the preparation and implementation of these complex and important plans.

A single pastoral lease is equivalent in size to a small wheatbelt shire. A management plan for a lease must handle the scale, diversity and uncertainty of the management environment encountered by the manager. It also needs to be adaptable to changing physical and socio-economic circumstances.

Planning for the overall management of a lease requires an evaluation of the alternative technical options which arise from the integration of the management needs of the base resources with the operation of the grazing animal enterprise. These technical options are considered in the light of the manager's aspirations and then a plan is defined.



Murchison pastoralists developing stocking rates for different pasture types at a Land Conservation District Committee workshop.

The components of a plan

A station management plan will include the following components:

- a description of the nature and condition of the range resources;
- the infrastructure (fences and watering points) requirements for management;
- recommended stocking rates for sustainable land use;
- recommendations for the treatment of specific land management problems.

An assessment of the total grazing pressure on the lease is important in setting the recommended stocking rates. For example, feral goat and red kangaroo populations are known to have increased under pastoralism and both animals compete with sheep and cattle for available feed. Similarly, the advantages that can be gained by reducing domestic animal grazing on specific areas can be lost because of the attraction of destocked areas to other uncontrolled animals.

Economic modelling information, drought strategies, remnant vegetation management and the control of other herbivores can also be components of the plan. The inclusion of these latter components will be largely determined by the station manager's requirements for detail. For instance, a station manager may require the plan to include and consider:

- information on contemporary and projected flock and herd production characteristics and financial returns;
- detailed contemporary and projected cash flow budgets;
- recommended drought strategies.

In some situations the need to accommodate multiple land use (Aboriginal living areas, mining, tourism) on pastoral land will have to be addressed by the station management plan.

The success of a management plan in meeting land management objectives is best evaluated by station managers using objective information about the change in the base resources (soils and vegetation) derived from range monitoring systems (see 'Monitoring Western Australia's rangelands' on page 15). Therefore each plan also defines the location of an appropriate monitoring network for the lease.

PLANNING FOR FUTURE DEVELOPMENT IN THE MURCHISON

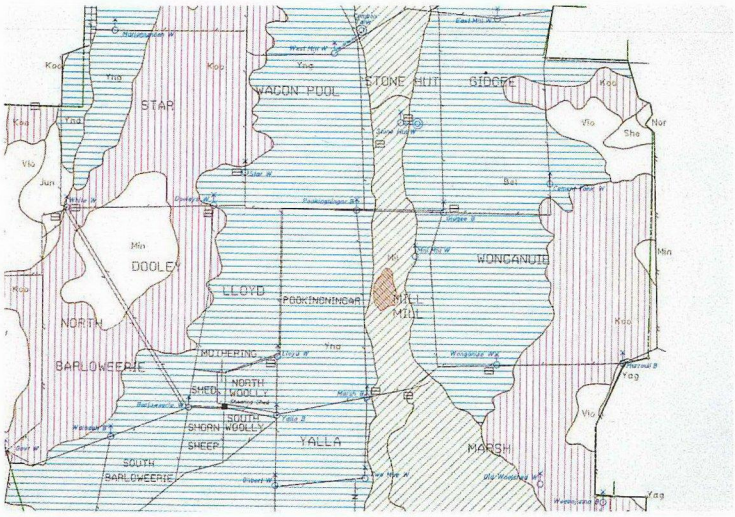


Photo 2 shows a result of the planning process. The plan now shows land systems.

This has prompted the pastoralist to re-fence the central paddocks to separate the sensitive and preferred Mileura land system (MIL) from the less preferred Belele (BEL) and Yanganoo (YNG) land systems, thereby creating two new paddocks ("Mill Mill" and "Stone Hut").

The planning process

Individual stations

Station managers are responsible for the development of the plans and are fully involved in their preparation. From their involvement they develop a commitment to implement the management strategies and tactics contained in the plan.

Their involvement in the planning process and a commitment to achieving planned outcomes is fundamental to the achievement of land conservation from management planning.

At a strategic level, station managers and Department of Agriculture staff use resource inventory and condition information (see 'Rangeland surveys: a basis for improved land use' on page 9) to determine the placement of fences and watering points, recommended stocking rates, and the distribution of the various classes of grazing animal.

At a tactical level the plan contains sufficient information to guide stocking decisions made in response to changes in seasonal and economic conditions and in response to the flow of range trend information from a range monitoring network.

The use of the resource inventory and condition information derived from the joint Department of Land Administration and Department of Agriculture surveys is fundamental to the whole station management planning process. There are no other technical constraints at the strategic level of planning, but further research culminating in the development of formal decision support systems is required for better tactical planning of grazing use.

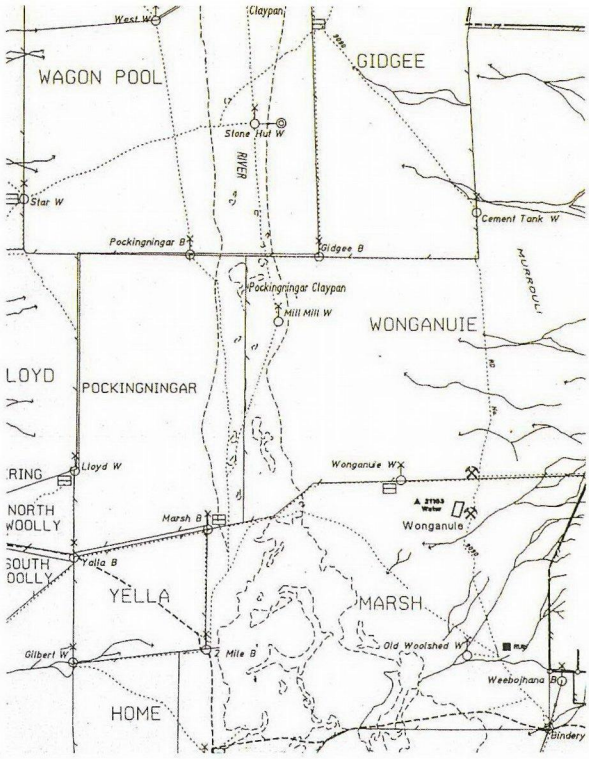


Photo 1 shows a traditional station plan

Communities

It is also important that the planning of pastoral land use occurs at a community as well as an individual level. This community level of planning is best achieved using Land Conservation District Committees as a focus for shared experience and understanding of pastoral management.

When pastoral managers have the responsibility for planning, they can draw on their own knowledge and skills, the expertise available within their community, and the services offered by private consultants and public agencies in the process of plan preparation.

An approach used in the Murchison Catchment within a National Soil Conservation Program project used pasture management workshops to develop land use standards that have since been incorporated within 20 station management plans prepared in that catchment area.

A similar approach to management planning is in progress with other Land Conservation District Committees.

The current focus on Land Conservation District Committees as the medium for the process encourages individuals to have ownership for the plans and for the achievement of the planned outcomes.

The Rangeland Management Branch is committed to developing station management plans with co-operating station managers. This activity is the centrepiece of the Branch's extension activities in the rangelands.

Rangelands have many users

Not all the clients of the Department of Agriculture's Rangeland Management Branch are pastoralists. Technical advice and technical supervision are provided for other users of the rangelands.

Shire and Town Councils, for example, have requested assistance and advice on techniques for the control of dust blowing into towns and down main roads from degraded landscapes.

Dust is also a problem in the numerous mining towns throughout the Western Australian rangelands. These towns have grown up in the immediate vicinity of mines originally for the convenience of the early mining pioneers.

The Department of Agriculture has provided technical supervision and support for projects, partially funded by mining companies, for the stabilization through revegetation of land disturbed by mining activities.

The following two articles cover examples of these activities from Carnarvon and Kalgoorlie.

Aerial view of the banana and horticultural plantations along the Gascoyne River, Carnarvon. The town of Carnarvon is at the top of the photo.

Plant regeneration and the control of dust on the South Common, Carnarvon

By Ian Watson, Adviser,
Rangeland Management Branch,
Carnarvon

River saltbush, silver saltbush, pig face and buffel grass have colonized the area inside one of the large ponding banks built in 1983. (Photo taken December 1987.)

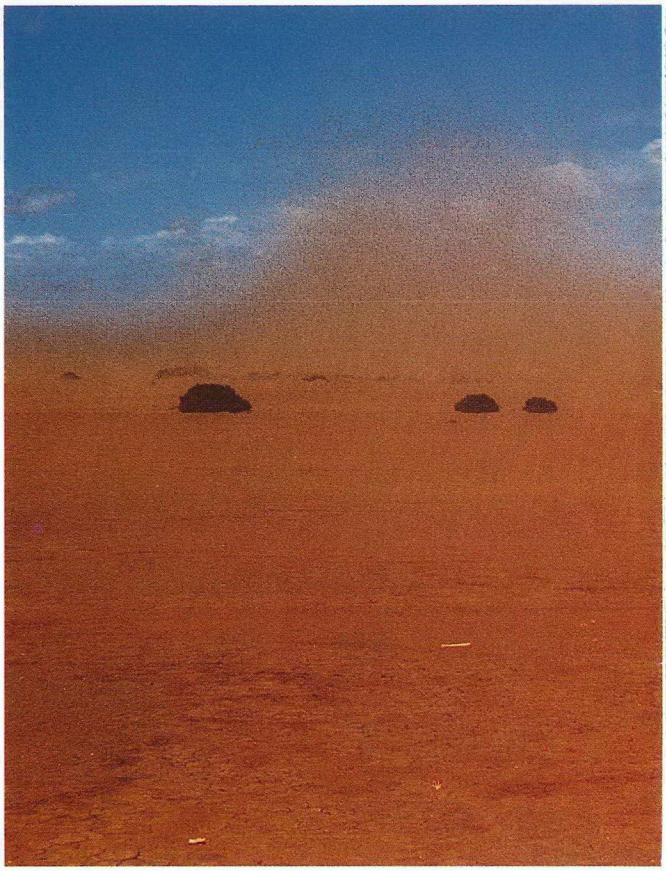
Like many old Western Australian country towns, Carnarvon has a public Common on its outskirts. In the days before motor transport this was the area where the town's animals were pastured.

Camel trains used for carting wool from the pastoral stations to the port camped there; saddle horses and donkeys when not being used were let loose on the Common. The odd dairy cow, goats and other domestic stock were all allowed to use the Common as a grazing area.

Even up to a few years ago town goats, recreational horses and stray cattle still grazed on this area south of town. In recent years four-wheel drive vehicles and trail bikes have had uncontrolled access to the South Common, thus increasing the destruction of vegetation and adding to the town's dust problems.

The result is that some of the land is degraded. Of the 1344 ha that make up the South Common, about 390 ha have been identified as being severely degraded.

A vegetative regeneration programme over the past 10 years, co-ordinated by the Shire of Carnarvon and the Department of Agriculture, has revegetated the worst areas, and considerably reduced the amount of dust that was regularly blown onto the town.

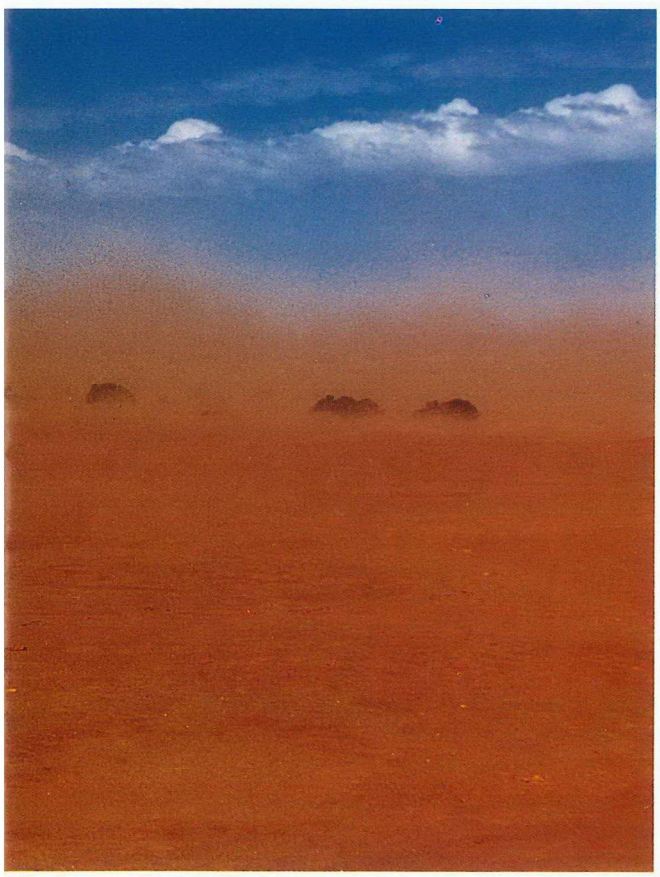


Physical features of the South Common

The Carnarvon South Common is inherently fragile. The reserve area is part of the Gascoyne River delta, close to where it drains into the waters of Shark Bay. The area is generally flat, sloping only about four metres across a three kilometre width from north-east to south-west.

The undisturbed soils comprise about one metre of sandy loam over 1.5 m of saline fine sandy loam to clay loam subsoil that contains up to 1 per cent total soluble salts. The subsoil is underlain by the coarse sands of an old river bed. The whole area is underlain by a highly saline watertable which, close to the coast, contains up to 7500 millisiemens per metre (48,000 parts per million) total soluble salts. This watertable is up to 50 per cent more saline than the nearby waters of Shark Bay.

The general topography consists of low sandy rises covered with saltbush, acacia shrubs and buffel grass. These rises remain as islands above the exposed saline subsoil. A combination of wind and water erosion following the removal of the vegetative cover has stripped as much as one metre of surface soil from these eroded areas. These areas, whch originally supported a mixture of saltbush, bluebush and rhagodia species, have since been revegetated as part of the South Common restoration programme.



The strong south-westerly winds that blow over the South Common of Carnarvon for most of the year cause severe dust problems for the town. This was one of the major factors in the decision to revegetate the Common.

The problems

The prevailing strong south-westerly winds blow much fine sand and dust from the eroded surfaces of the Common onto the town. In addition, the eroded landscape is readily visible from the south along the major highway and is an eyesore to townspeople and visitors alike.

Carnarvon's climate does not encourage rapid revegetation. It is semi-arid, with rainfall over the past 40 years ranging from 75 mm to 557 mm a year, with an average annual rainfall of 230 mm. Fifty-four per cent of this rain can be expected during May, June and July. Cyclonic disturbances can bring more rain in January, February and March. Average annual evaporation is almost 12 times the rainfall.

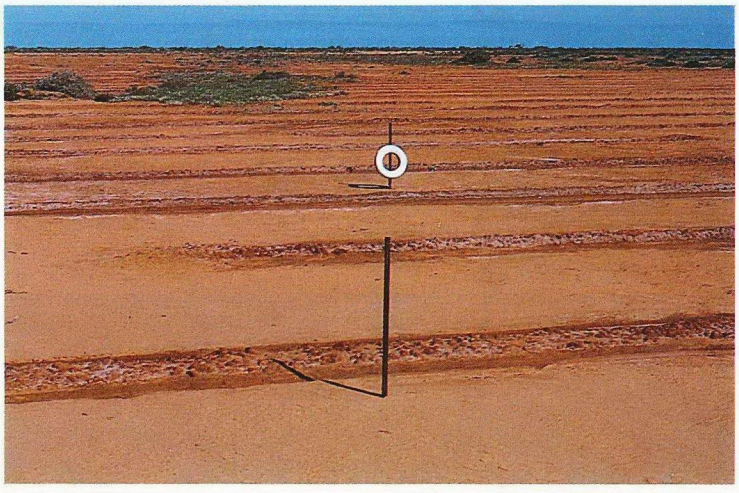
Unlike the inland parts of the Gascoyne, the Carnarvon area is generally cooled by a strong sea breeze. It is this wind, sometimes gale force and prevailing from the south-west, that causes most of the dust problems. The wind is strongest over summer when the soil of the South Common is normally driest and most liable to erosion.

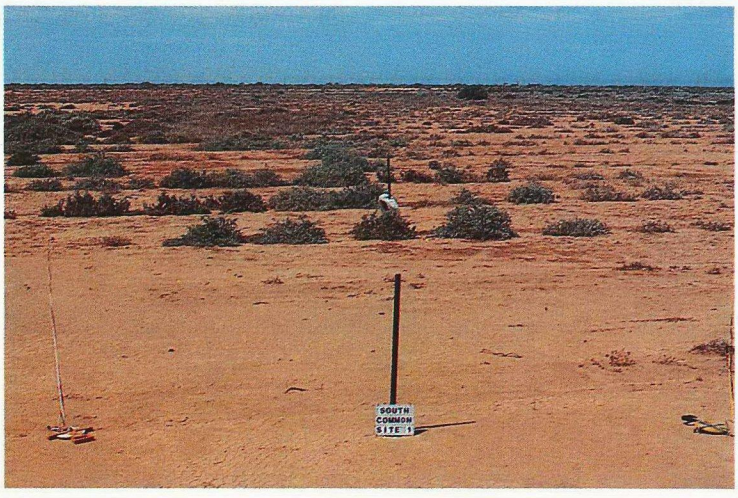
Early attempts at regeneration

Early attempts at restoring the South Common began in 1956 when the Department of Agriculture undertook a major rehabilitation project on a portion of the eroded area. A 400 mm mouldboard plough was used to construct small water ponding banks over much of the Common. Although the area was not seeded, growth of volunteer (self-sown) species was encouraging. However, uncontrolled grazing by feral and domestic animals largely destroyed the new plant growth.

This lack of control highlighted another of the problems that made restoration inherently difficult - ownership of the land. The Carnarvon Shire was unable to control land use because it did not own the land. The degraded area on or near the South Common was part of some 16 separate government reserves. The Department of Lands and Surveys (now Land Administration) held the largest block. In 1971, for example, when contour ripping and reseeding cost $1/acre ($2.47/ha), $100 was approved for expenditure on the restoration programme. However, the programme was not implemented.

(Below) One of the rangeland monitoring sites set up on the South Common. This photo was taken in July 1983, soon after cultivation with an opposed disc Mallen Seeder. A large amount of salt remains on the surface of the cultivation and there is a lack of growth on degraded duplex soil.





The same site in January 1988. Shrubs have continued to grow and colonize the area.

The final planting programme, postponed a year in response to above average winter rainfall in 1982, was finished in June 1985. The Carnarvon Tree Society and children from loca schools planted 1000 trees, mainly coolabah and tamarisk.

A field "laboratory"

The nearness of the South Common to the tow allowed the Department's Rangeland Management Branch to test many different cultivation techniques, shrub species and propagation methods from 1982 onwards. Range regeneration was becoming an increasingly important aspect of the Branch's research and advisory programme, and the South Common became an ideal "field laboratory" on which to test new techniques.

Formation of a soil conservation district

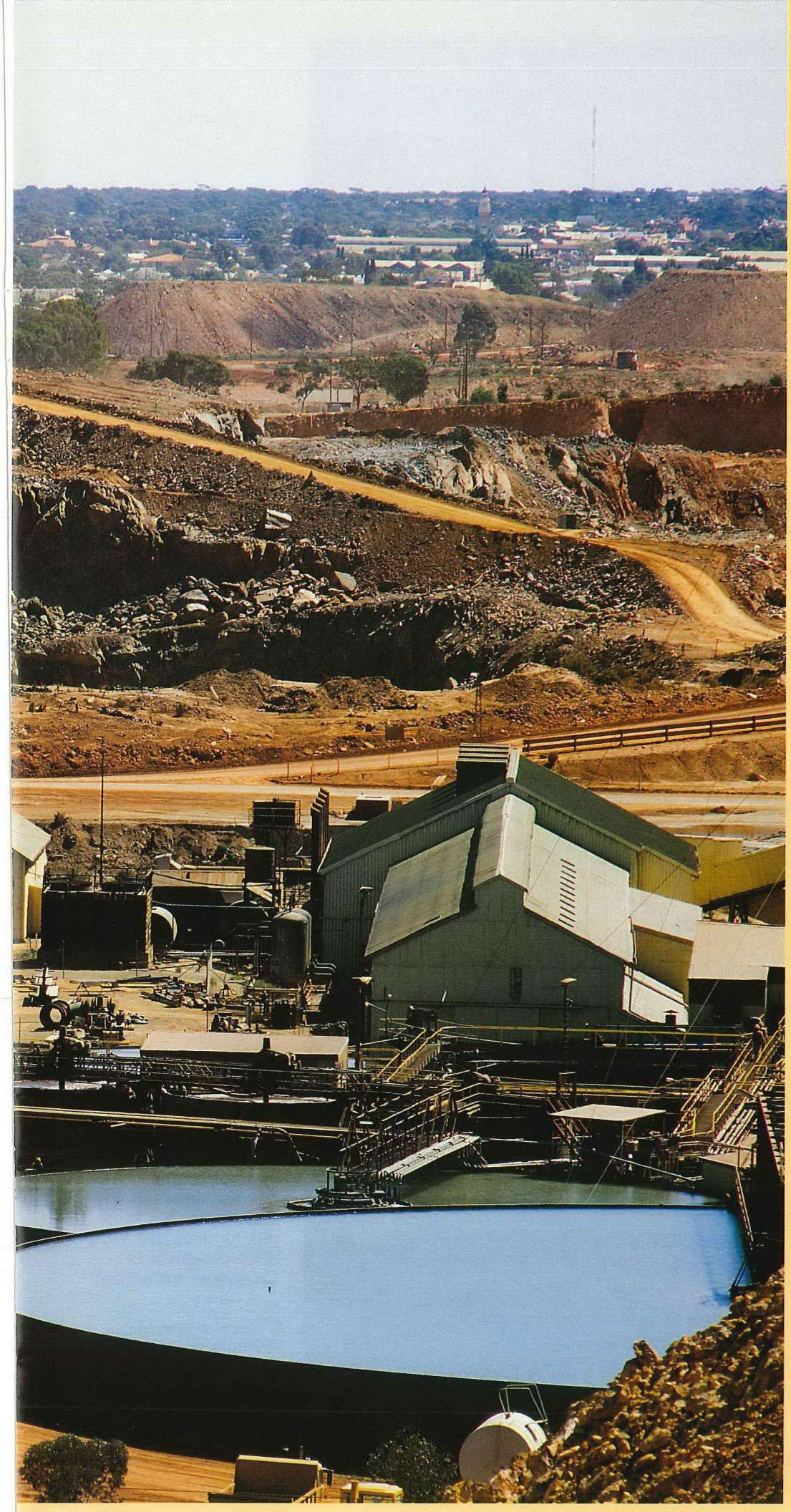
The Carnarvon Soil Conservation District was formed partly as a result of local interest and enthusiasm created by the rehabilitation of the South Common, and the perceived need to restore other degraded areas within the region

No further large cultivation projects are planned for the South Common. The Carnarvon Soil Conservation District continues to tak an active interest in the South Common. It has expanded its activities to include recommenda tions for land use for the release of Crown lanc for sale, management of the National Park reserve along the banks of the Gascoyne River and administration of the District's tractor, which is now almost permanently on hire to pastoral Soil Conservation Districts in the Carnarvon area.

The future

The South Common is still no verdant oasis and it may never again show the dense stands of saltbush and bluebush shrubland that existed before settlement of the town. However, vegetative cover has improved considera bly over the past 10 years and the Common represents a much reduced dust hazard for the Carnarvon township.

The success of the South Common revegetatio and dust abatement work has shown that Shir Councils, local communities, government departments and other organizations can work together to make a positive contribution towards soil conservation. A problem was identi fied, objectives were set and work was implemented. The success of the project vindicates the time and effort spent on it.



Mine dumps, dust and towns

Rehabilitation of mined areas and control of dust in the Goldfields

There is a warren of shafts beneath the gold mining town of Kalgoorlie. The townspeople, the mines and the dust live side-by-side.

Rehabilitation of mined areas and control of dust at Kalgoorlie and Boulder

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One of the lesser known roles of the Department of Agriculture is advising on aspects of managing and rehabilitating non-agricultural land. This advice and research is directed mainly at minimizing the effects of land degradation and providing land resource data and land capability assessment maps to assist regional planners.

An interesting aspect of this work is stabilizing sites disturbed as a result of recent mining, and rehabilitating old mined areas, particularly along Kalgoorlie's Golden Mile. The tailings dams and overburden dumps of the gold mines can, in some circumstances, be a source of blowing dust which poses a problem for residents.

With assistance from the mining industry, the Department of Agriculture's Kalgoorlie Regional Office has co-ordinated vegetative rehabilitation programmes for several of these problem sites. Saltbushes and bluebushes now grow in what is usually a hostile environment for plants, and the amount of dust generated from these sites has been reduced.

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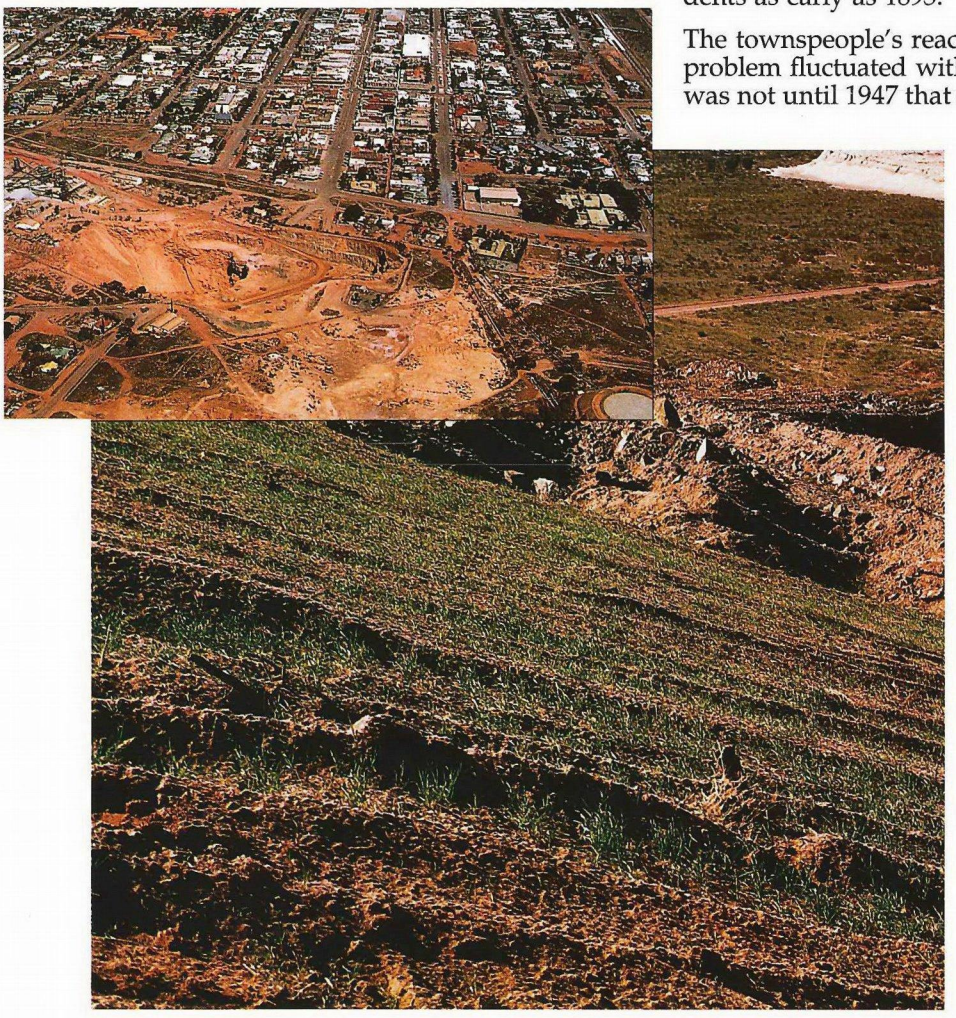
Historical background

Western Australia's twin gold mining towns of Kalgoorlie-Boulder developed as a result of Paddy Hannan's find in 1893, and since then the towns have been linked with gold production. The first gold rush brought people and prosperity to the area, but it also changed the surrounding environment. To service the mines and towns, more than 25 million tonnes of timber was cut from the surrounding woodlands between 1894 and 1965.

The woodland around Kalgoorlie is uniquely productive for a semi-arid climate. Salmon gums (*Eucalyptus salmonophloia*), gimlets (*E. salubris, E. campaspe*) and other species were logged over an area of 30,000 sq. km, the logging being made easier by an existing railway system which extended for more than 400 km. This loss of vegetation from around the town, and the practice of dry blowing to extract gold from the crushed ore, lead to blowing dust causing problems for the residents as early as 1895.

The townspeople's reaction to the dust problem fluctuated with the seasons, and it was not until 1947 that a regeneration committee was formed to combat the problem. The committee was abandoned three years later, following seasons of good rain. The present Goldfields Dust Abatement Committee was initiated after publication of a 1973 report on the dust problem in the Kalgoorlie - Boulder region, and the Department of Agriculture has been directly involved with dust abatement in Kalgoorlie since then.



☐ Kalgoorlie and Boulder have developed close to the mined areas.

☐ One of the overburden slopes that has been revegetated. The W.A.M.P.R.I. project is generating valuable information on the requirements for successfully establishing vegetation on overburden dumps near Kalgoorlie.

Aspects of the mining process

Dry blowing is seldom used on the Golden Mile to win gold from the earth, except on smaller leases. Today, gold is mined by both underground and open cut methods. Gold-bearing ore is sent from the mine to the mill where it is processed chemically to extract the gold. After milling, some ore must be heated to high temperatures in specially built roasters, and the waste product from this milling operation is known as tailings or slime.

Most of the material mined underground is ore which can go directly to the roaster or mill because the miners can select the type of material to bring to the surface.

With open cut mining, however, large amounts of material which do not contain economic quantities of mineral must be removed to reach the gold bearing ore. This waste rock is known as overburden and is carted away from the pits to large overburden dumps 45 m high.

Tailings dams

Tailings material is rock that has been finely ground and chemically treated to extract the gold. After treatment, the tailings is piped away from the mill in a slurry to disposal sites called tailings dams. When these dams dry out they are known locally as slime dumps. After almost a century of mining an arc of some 30 slime dumps covering 400 ha dominates the south-eastern part of Kalgoorlie - Boulder, only a kilometre or so from residential areas. The 1973 report identified these dumps as being a major cause of dust.

Rock mulching

Initial attempts at stabilizing the surface of slime dumps against wind erosion and generation of dust concentrated on using a rock mulch because the tailings is known to be a hostile environment for plant growth. It has a high salt content (generally about 1 per cent total dissolved solids), poor physical composition and is low in plant nutrients. Although rock mulching initially appeared favourable, it was abandoned because of problems with the type of material used, the application method and the presence of large amounts of drift sand outside treated areas. Vegetative stabilization techniques were then tested.

Establishment of vegetation

Since 1980, the Department of Agriculture has tested vegetative establishment on the surface of the South Chaffers tailings dam. Various saltbush species were tested for their ability to establish and grow in the tailings. The present recommendation is for a 'shot gun' mixture of six species, the most successful of which are shown in Table 1.

Table 1. Performance of revegetation species at various sites, ranked 1 to 5, 5 being the best performance

Botanical name	Common name	Type of site A	B	C	D	E	F
Atriplex amnicola 577	River saltbush	4					
Atriplex amnicola 949	River saltbush	5	4				
Atriplex bunburyana	Silver saltbush	3	3	5			
Atriplex lentiformis	Quail bush				3		
Atriplex nummularia	Old man saltbush	1	2	3		4	1
Atriplex semibaccata	Creeping saltbush			1			
Atriplex sp	'Pintharuka'		5	4	1	2	
Atriplex stipitata	Bitter saltbush	2		2	4	1	4
Atriplex undulata	Wavy leaf saltbush		1		2	3	3
Atriplex vesicaria	Bladder saltbush				5		
Maireana brevifolia	Small leaf bluebush					5	2
Maireana pyramidata	Sagobush						5

Sites
A: Rangelands - Leonora : Seeding
B: Rangelands - Leonora : Planting
C: Overburden - Kalgoorlie : Seeding - 1986
D: Overburden - Kalgoorlie : Seeding - 1987
E: Overburden - Kalgoorlie : Planting
F: Tailings - Kalgoorlie : Seeding

□ The two major waste products from today's gold mining operations are tailings and overburden.

□ Technical officer Mary Fletcher collects seeds from a three-year-old *Atriplex nummularia* (Old man saltbush) growing on a tailings dam.

Grader-built absorption banks constructed along the contour control surface run-off from the tailings dam and ensure that as much water as possible is trapped and made available to the plants. Fertilizer is essential for good plant establishment. The application of 400 kg/ha of single superphosphate plus trace elements has produced good results.

The Goldfields Dust Abatement Committee is confident that most of the old tailings dams around Kalgoorlie can be stabilized vegetatively to reduce their potential to generate dust by using the techniques described.

Rain over many decades has leached salts from the surface of some of these tailings dams, thus improving the chances of establishing vegetation. Fresh water was used in the construction of other tailings dams and plants establish well on the surface of these dams, given favourable conditions.

In contrast, hypersaline water with salt contents exceeding 5 per cent is used in the construction of tailings dams today, and it is these dams that the Goldfields Dust Abatement Committee wants to stabilize soon after completion. The Department of Agriculture and the Goldfields Dust Abatement Committee are keen to start research on this new generation of tailings dam to find a successful vegetative stabilization technique.

Overburden dumps

The ratio of open pit ore to underground ore mined on the Golden Mile has almost doubled in the past six years. This expansion in open cut activity has resulted in more disturbed land near the town. These new overburden dumps are a prominent feature of the local landscape.

While their potential to generate dust is not as great as those of the finely crushed tailings material, the overburden dumps will contribute to the dust problem until their surfaces are stabilized against water and wind erosion. The establishment of a stable, low maintenance plant cover on the dumps would minimize their potential to be "blown" and improve the atmospheric and aesthetic environment of both towns.

A new industry-funded project

Department of Agriculture salinity research officer, Clive Malcolm, and soil conservation officer, John Quilty, proposed a three-year research project to the Western Australian Mining and Petroleum Research Institute to study the establishment of vegetation on the overburden dumps. The project started in early 1986 with financial support from North Kalgurli Mines Ltd and Kalgoorlie Mining Associates.

As part of the proposed revegetation programme, the project team had to consider the rehabilitation goals, the climate, the composition of the overburden material and other relevant site characteristics. One long-term goal is to establish a stable community of plants which is resilient to and compatible with the surrounding environment and land uses. A practical short-term goal is to establish vegetative cover rapidly which can protect the soil surface from wind and water erosion. Different strategies and species may be required to achieve both goals.

Climate

Kalgoorlie has a semi-arid climate, with an average annual rainfall of 253 mm and an average annual evaporation of 2436 mm. There is no distinct rainy season but most shrubs for revegetation programmes are seeded or planted in autumn when soil moisture is best. There can be extreme variations in temperature during the year and vegetation may have to cope with temperatures ranging from -5°C in winter and 50°C in summer.

Site characteristics

The slope of the site and the nature of the overburden determine how revegetation can be achieved. The quality of the tailings "soil" particularly will influence what species should be planted, while the slope has a bearing on what vegetation techniques can be used.

Analysis of the mining overburden shows that it has high levels of salt and sodium, it has poor physical structure and it is low in nutrients. The type of material varies across a dump and also with depth.

Revegetation species

Forty plant species have been screened for their ability to establish and grow in the overburden. The most successful group were the saltbushes, although some acacias and eucalyptus have grown well. Table 1 lists the most successful species grown in various environments.

Various saltbush species will be required to rehabilitate different environments, and a mixture of species will offer the greatest probability of success.

Plant cover on slopes

Several techniques were tested to establish plant cover on slopes of overburden dumps of varying steepness. When the overburden is tipped from large trucks it forms a slope of 37 degrees from the horizontal. These slopes resist the establishment of vegetation despite the use of specialized techniques which apply seed, fertilizer and a protective mulch to the slope.

Establishment has proved successful, however, where slopes have been reduced to 18 degrees or less and covered with topsoil. In one instance, the local street sweepings were spread over a batter as a substitute topsoil and provided an excellent growth medium. Perennial saltbushes established readily and some garden vegetables and exotics made a brief appearance.

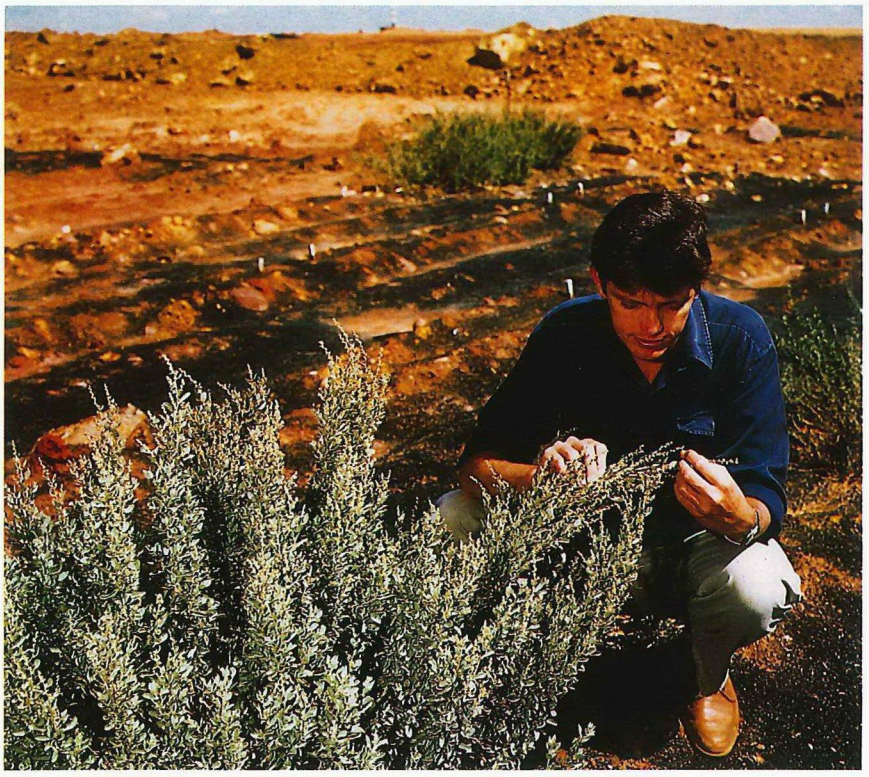
Establishment

The Department of Agriculture's Mallen Niche Seeder has been used successfully to direct seed shrubs on the flat tops of overburden dumps. Transplanted seedlings have grown well provided they are mulched, fertilized and watered during the first summer.

The success of either direct seeding or transplanting seedlings depends on the preparation of the overburden before seeding or planting. Drains must be constructed to combat water erosion and to trap as much water as possible for the plants. Traffic-compacted areas must be ripped to alleviate soil compaction. Areas to be vegetated must be fenced to keep out people, vehicles and uncontrolled grazing stock.

Conclusion

Rehabilitation of mined land is most effective when adequate planning has preceded development to identify the many requirements of a successful programme. The work by the Department of Agriculture, through the Western Australian Mining and Petroleum Research Institute project, and its involvement with the Goldfields Dust Abatement Committee, is helping to define these requirements. The successful revegetation of some mining wastes near urban centres will reduce wind and water erosion, thereby minimizing the potential for blown dust. It will also improve the visual environment for residents and visitors alike.



The author in one of the overburden dumps on which salt-tolerant shrubs are now growing.