On farm

MEAT & LIVESTOCK AUSTRALIA

# Grazing Land Management

*Education Package*
*Technical Manual*

**Project number NAP3.325**

**Final Report prepared for MLA by**:
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Natural Resources

# CHAPTER 1: INTRODUCTION

This technical manual is designed to complement other parts of the Grazing Land Management (GLM) workshop. Specifically, it provides a more detailed explanation of the key concepts and principles, often with examples from research or on-property demonstrations.

The emphasis in this manual is on general principles and concepts that apply across the grazing lands of northern Australia (Queensland, Northern Territory and the Kimberley and Pilbara regions of Western Australia). The workbook and other materials provided in the GLM workshop are designed to illustrate the relevance and practical application of these principles and concepts to a particular region. For example, while the principles for the use of fire are generally common across northern Australia, the practical relevance and application of fire management can vary widely: compare, for example, the Katherine region with the mitchell grasslands of central-western Queensland. So, the workbook and case study property complement this manual by focussing on the particular relevance and practical application of the principles and concepts to the local region.

Use this technical manual to clarify concepts and ideas or to explore them in more detail.

**A framework for organising information about grazing land management**
A lot of information will be presented, discussed and debated during the GLM workshop and it is useful to have a framework that can help capture, organise and prioritise the key points and principles. Such a framework is presented below.

The framework organises information around 3 'gateways', with each gateway leading to sustainable livestock production from grazing lands (Figure 1). The 3 gateways are:

1. Improving **rainfall use efficiency**: optimising the use of rainfall for the production of useful forage, by optimising *land condition.*
2. Improving **utilisation rate**: optimising the harvest of forage by livestock, by optimising *level and evenness of grazing.*
3. Improving **conversion efficiency**: optimising the conversion of forage eaten to animal product, by optimising *diet quality.*

Note that we want to optimise, not maximise. Maximisation is not consistent with either the best economic outcome or with sustainable use.

Sustainable use has two components:
1. Ensuring the land remains productive into the future: maintaining good land condition is consistent with this.
2. Helping to ensure that future generations have the same options that we have: this requires consideration of broader environmental issues like conservation of biodiversity.

Our approach to grazing land management will therefore focus on:

- Improving land condition
- Improving evenness of use
- Improving diet quality

At the same time, we will look for additional opportunities to contribute positively to the environmental status of the catchment or region.

We will first look at understanding the grazing ecosystem. We will then look at the tools available to manage land condition, to improve level and evenness of use and to enhance diet quality. These tools are:

- Managing grazing
- Using fire
- Managing tree-grass balance
- Using sown pastures
- Managing weeds

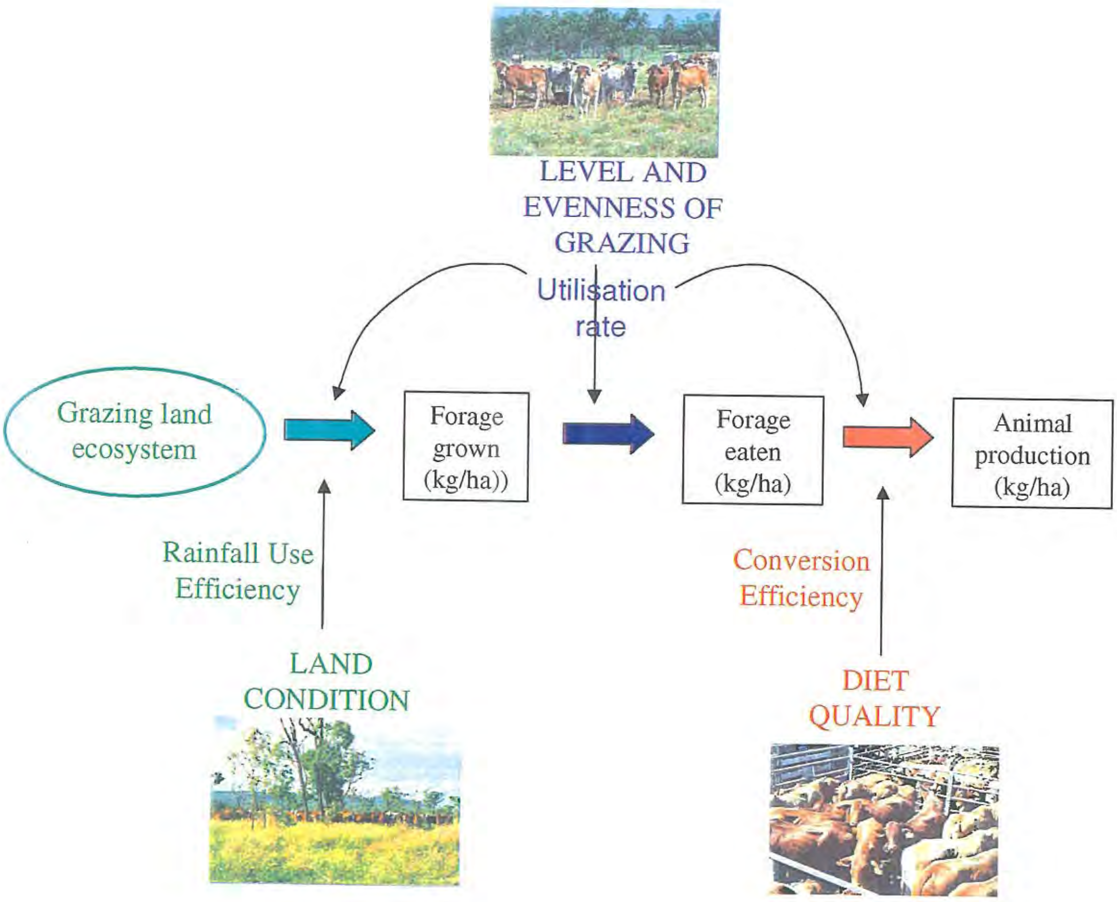



**Figure 1. The 'gateways' model for organising information about grazing land management**

# CHAPTER 2: UNDERSTANDING THE GRAZING ECOSYSTEM

## 2.1 Meeting the need for both production and healthy land - searching for sustainability

Management of grazing lands has two over-riding concerns or desired outcomes:

1. optimising animal production and
2. keeping the land healthy and productive.

These outcomes are consistent with the goal of 'sustainable production from grazing lands'. However, sustainability can be like beauty: it is in the eye of the beholder. So we need to come to some common understanding of the concept.

Sustainable use or management involves some key concepts:

- using resources for both material and non-material well-being
- there are limits to the environment's ability to meet present and future needs
- the need to consider inter-generational equity: the actions of one generation should not reduce the welfare of future generations;
- economic considerations are important in defining sustainable land use;
- the precautionary principle - where there is reasonable evidence of serious threats to the environment, then a lack of complete scientific certainty should not be used as a reason for postponing measures to prevent environmental damage.
- there are three interdependent components that operate in sustainable land use: ecological, economic and social (Figure 1).

We need to challenge the view that has development (or economic productivity) and environmental conservation as conflicting and mutually exclusive aims. A more realistic view is that economic productivity and a well-managed environment are fundamentally linked. Development cannot persist upon a land base that is deteriorating: we need to retain the value of our renewable resources like land and water. Equally, without development, there is not much room for sustainable use: without the capacity to grow and improve living standards there is little scope to move beyond subsistence and to focus on the needs of others.

Grazing lands are ecosystems, that is, a mix of organisms interacting with each other and with the environment. Ecology is the study of how ecosystems work. Therefore, an ecological approach to grazing land management is consistent with ensuring both optimum productivity and healthy land. *This manual will build an ecological approach to grazing land management.*

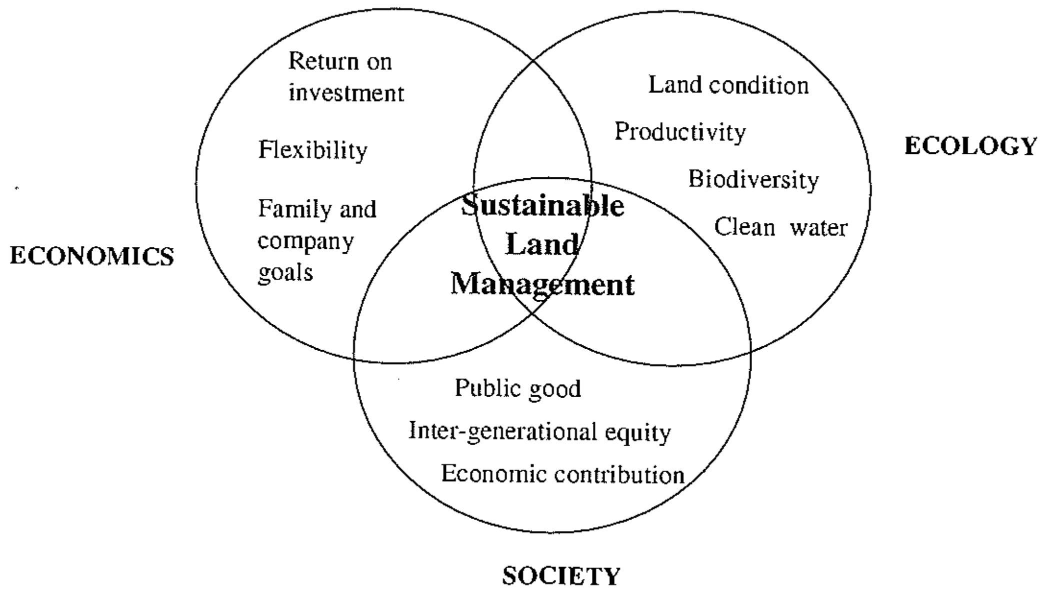



**Figure 1. The three inter-dependent components of sustainable land management: economics, ecology and society.**

### *2.1.1 What is healthy country?*

Management of grazing lands is primarily concerned about what is happening in a paddock or across a property. However, to really assess the health of a whole catchment or region, we also need to look at what is happening across properties and other land uses.

The health of land across a region or catchment can be assessed on 3 key criteria:

- the key ecological processes (energy flow, nutrient cycling, water cycling) are maintained throughout the area
- the region maintains viable populations of all native species of plants and animals, and grazing lands contribute to this maintenance
- the various needs of people with an ongoing interest in grazing lands are recognised.

Table 2 provides suggestions about the attributes we would look for to check on the health of a catchment or region. We will be primarily concerned with the attributes for a paddock and a property, but we will also consider the needs for the catchment or region.

This sort of framework helps select the appropriate attributes to be used for different situations, eg, it is appropriate to expect a healthy paddock to have stable soil producing to its potential, but it is may not be appropriate to expect a healthy paddock to have viable remnants of all ecosystems. Similarly, areas of improved pasture may contribute to a healthy paddock but improved pasture across the whole catchment would be considered unhealthy.

**Table 2 Attributes of healthy country for a paddock, a property and a catchment or region.** (note that the attributes for a healthy paddock are necessary for a healthy property; similarly, attributes for the paddock and property contribute to the health of the catchment or region)

| Paddock | Property | Catchment or region |
|---|---|---|
| • Key ecological processes (energy flow, nutrient cycling, water cycling) are maintained<br>• Stable soil producing to its potential<br>• Perennial grasses dominant<br>• Balance of woody plants and pasture | • Viable remnants of all ecosystem types originally present<br>• Minimal leakage of nutrients, sediment, weed seeds<br>• Viable rural enterprise | • Network of ecosystems managed to conserve native plants and animals<br>• Viable rural community (people able to live and access services sufficiently) |

### *2.1.2 Ecosystems and land types*

Ecosystems are communities of organisms (microbes, plants and animals) and their environment (soil, climate). What is defined as an ecosystem depends on the purpose, management option or study in question. For example, the rumen of a cow, a termite mound and a woodland may each be considered ecosystems depending on the issue being addressed.

The components and processes of ecosystems are inter-connected and are constantly changing and active; ecosystems provide important "functions" (eg, nutrient cycling, energy flow) that keep the ecosystem ticking over. These functions are like the fuel and cooling systems of an engine. If these functions fail, then the ecosystem fails, and the productivity of the ecosystem, as well as the number and variety of organisms, will decline.

For our purposes, we will consider a land type to be an ecosystem. A land type (or grazing land type) is a discrete type of grazing land – an area of grazing land with a characteristic pattern of soil and vegetation.

Grazing lands are land types, or ecosystems, linked together. A paddock may contain one, several, or many land types, depending on the size of the paddock and on how variable the country is.

### *2.1.3 Condition of grazing land*

Grazing land condition (land condition) is the capacity of land to respond to rain and produce useful forage.

Land condition has 3 components:

- soil condition: the capacity of the soil to absorb and store rainfall, to store and cycle nutrients, to provide habitat for seed germination and plant growth, and to resist erosion;
- pasture condition: the capacity of the pasture to capture solar energy into palatable green leaf, to use rainfall efficiently, to conserve soil condition and to cycle nutrients;
- woodland condition: the capacity of the woodland to grow pasture, to cycle nutrients, and to regulate ground-water.

Soil condition is measured by the amount of ground cover, the infiltration rate, and the condition of the soil surface. Pasture condition is measured by the botanical composition, density and vigour of perennial grasses. Woodland condition is measured by the balance of woody plants and pasture in different land types and at different locations in the landscape. 'Landscape" refers to the stretch of country across a paddock or property, including the ridges, crests, hill-slopes, flats and drainage lines.

Degradation of grazing land is the loss of land condition. In the early stages of degradation, the condition of land is responsive to a change in management. Degradation is judged to be severe if it is irreversible over a reasonable time scale and/or it is expensive to rehabilitate.

### *2.1.4 Biodiversity*

Biodiversity is the variety of life. Healthy landscapes conserve biodiversity. An objective of sustainable grazing land management is to contribute to the conservation of biodiversity.

Ecosystem diversity is the variety of habitats, biotic communities and ecological processes. Species diversity is the number of species and their relative abundance in a defined area. Genetic diversity is the variety of genes contained in all the species in a given area.

Biodiversity contributes to the economy by providing food, medicine, industrial use, recreation and tourism uses. It provides 'ecosystem services' like photosynthesis, decomposition and water cycling, as well as contributing to aesthetics and culture. Biodiversity provides ecosystems with:

- resistance - the capacity to resist disruption from fire, floods, drought, human activities; and
- resilience - the capacity to recover from disruption.

*2.1.5 Guiding principle of grazing land management*

Our aim is to manage grazing lands in a way that ensures future generations have the same options that we have. This is a guiding principle for grazing land management.

## 2.0 What makes up grazing land ecosystems?

Grazing land ecosystems are made up of living (plants, animals, microbes) and non-lining components (soil, climate). Most living things in grazing land ecosystems are native species, ie, they originate from the area, but some will be exotic species, ie, species introduced from elsewhere (usually from overseas). Some exotic species have become naturalised: they are so well adapted to their new environment, they persist and spread.

### *2.2.1 Plants*

Vegetation is the most conspicuous feature of grazing lands. The mix of vegetation types occurring on a discrete land type, or ecosystem, is called a plant community. The vegetation in the plant community is made up of the herbaceous (grass-dominant) layer and, where present, the woody layer. Plants are the "primary producers", they capture solar energy and convert it into living tissue for use by other species.

There are three main plant types:

- Annual herbs (herbs are plants with non-woody stems: grasses and forbs)
- Perennial herbs, especially the perennial grasses
- Shrubs and tress

We will focus on the role of plants in maintaining productive grazing land ecosystems, especially the role of perennial grasses. Grasses are better adapted to defoliation by grazing or fire than other plant types, because the growing points are generally close to the ground. The growing points of a perennial grass are kept low to the ground until the stems elongate prior to flowering.

Annual grasses are more variable in growth from year to year, compared to perennial grasses, and do not provide continuity of either ground cover or forage supply (Figure 2).

The unit of grass growth is the tiller (Figure 3). Tillers live for only 6-12 months. Perennial grasses have the ability to produce additional crops of tillers, so that the grass plant can live for several years. Plants with tillers that develop an upright habit take on the typical form of tussock grasses: most native grasses are tussock grasses. Plants with tillers that may grow close to the ground or underground take on the creeping or prostrate form typical of grasses like indian couch.

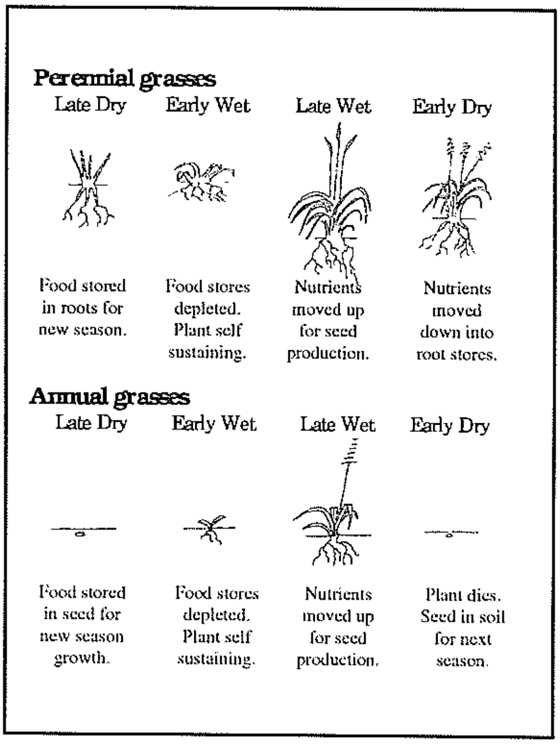



**Figure 2. The differences in life cycle between perennial and annual grasses**

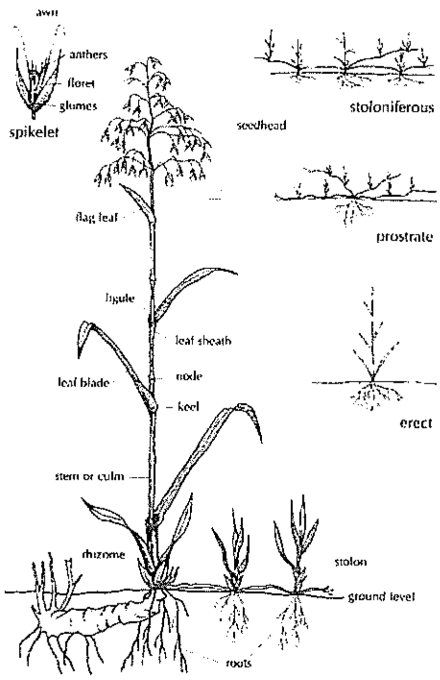



**Figure 3. The general structure and growth forms of grasses**

Some perennial grasses have a short life span (eg, 2-4 years for Queensland bluegrass), while others live for many years (eg, >10 years for Mitchell grass). The shorter-lived the species, the more important is seed production to ensure its persistence.

For example, Figure 4 shows the likely rates of decline in plant population for different plant types, assuming that there were 100 individuals of each type initially and that all seedling regeneration was prevented. Annual plants are clearly most dependent on seedling regeneration, trees are least dependent, and perennial grasses are intermediate. Grasses like Queensland bluegrass live for only a few years and its presence in pastures tends to vary with year-to year variation in rainfall. In contrast, mitchell grass is long-lived and its presence in pasture is relatively stable.

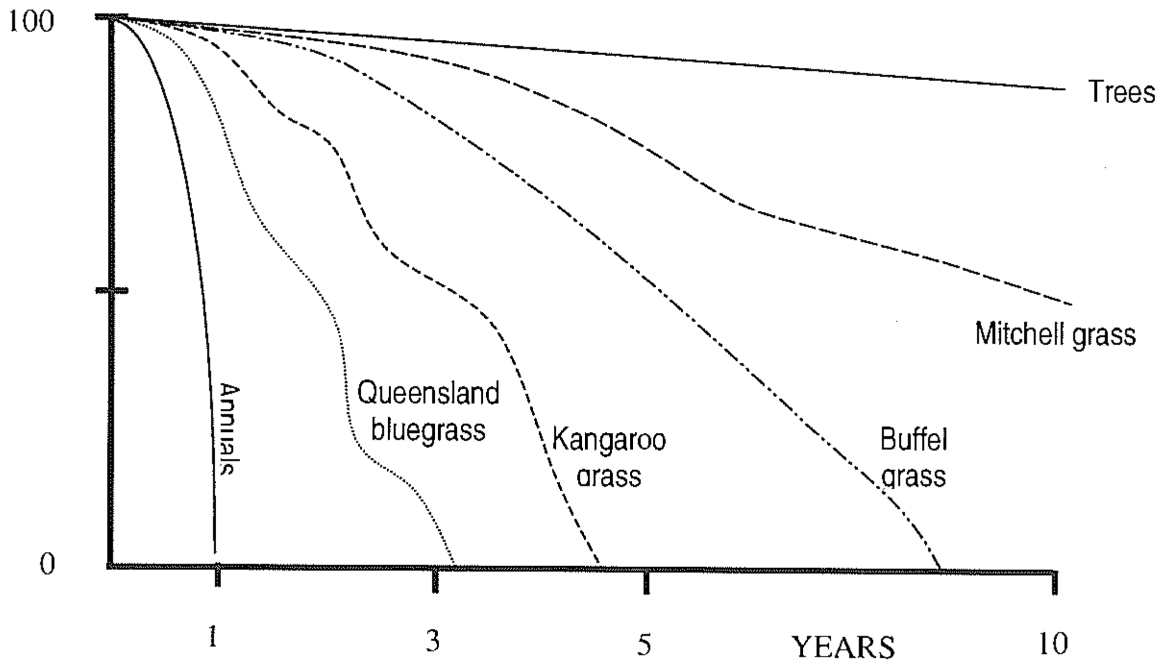



**Figure 4. The relative importance of seed production for persistence of different plant types depends on their life span** (see text for detailed explanation).

The structure (height and density of plants) and species composition of plant communities change over time. This is in response to variation in rainfall and other factors such as grazing and fire. These changes may occur rapidly or may be gradual (occurring over years or decades).

Consistent grazing pressure tends to favour some species over others. Species that decline under persistent grazing are called decreasers; those that are favoured by persistent grazing are called increasers.

Both sharp and subtle variations in a plant community can occur over a paddock, associated with local variation in soil and microclimate.

### *2.2.2 Animals*

Grazing animals are the most conspicuous type of animal in grazing lands, but a variety of other types occur.

Animals are classified as:

- Herbivores: plant eating (grazing animals feed mainly on grasses and forbs; some animals feed mainly on browse eg, koalas; while others feed mainly on fruit and seed eg, birds)
- Carnivores: consume meat, eg, wedge-tail eagles, dingoes
- Decomposers: some animals consume dead matter, eg, earthworms, dung beetles, termites.

Grazing animals are selective in what they eat: they tend to prefer some plant species over others. Their preferences for plant species are driven by the quality and ease of harvesting of various plants, but are constrained by the animals' body size. For example, large animals like cattle need to process a large amount of forage through their digestive system (which is a large proportion of their body weight), so cannot afford to be too selective. Cattle diets are mainly grass but may contain significant amounts of forbs and browse at certain times.

Small herbivores like goats and the smaller macropods cannot process as much forage through their digestive system (which, compared to cattle, is a smaller proportion of their body weight) so need to be more selective. These smaller animals tend to consume a variety of plant species and the diet may not be dominated by grass.

Soil animals are also important parts of the ecosystem: these decomposers help breakdown plant litter and other organic material.

Grazing lands support a wide variety of native animals: birds, reptiles, mammals, amphibians, fish and invertebrates. Feral animals have become naturalised in many regions: for example, pigs, rabbits, foxes, cats, donkeys, horses, camels, cattle, and some bird species.

We will focus on the management and productivity of grazing animals. However, we will also emphasise the critical role of soil organisms, the effects of management on conservation of native animals, and the impact of feral animals.

### *2.2.3 Soils*

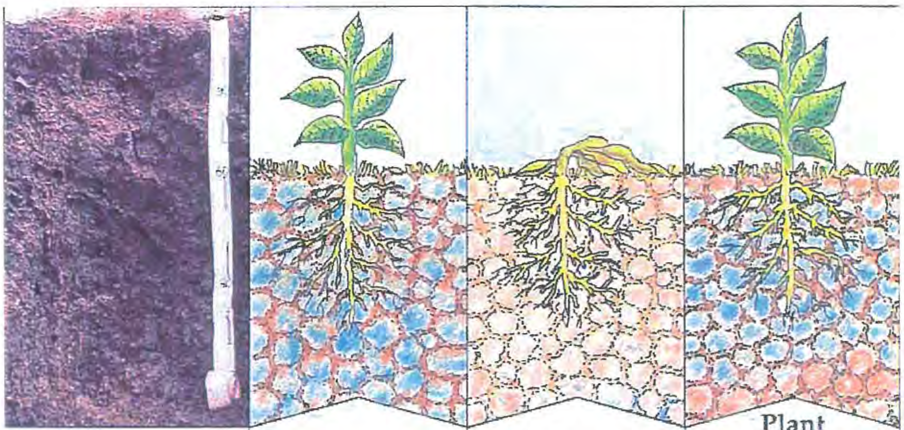
Soil is made up of minerals, organic matter and living things (soil animals, microbes). Type of parent material (such as granite, sandstone and other rocks), climate and topography interact over time to form different types of soil.

The condition of soil is often ignored when managing grazing lands: most focus if given to animals, and then pasture. However, the soil type and its condition is a major driver of pasture and animal production. Many of the benefits of improved grazing land management are due to its effects on soil characteristics, so a working knowledge of soils is important.

Soil characteristics such as texture, structure, fertility, and organic matter content depend on the mix of minerals, organic matter, organisms, water and air that occur in a particular soil type, as well as processes like erosion and the amount of soil being deposited.

***Soil texture*** depends on the relative proportions of clay, silt and sand. Soil texture influences:

- Fertility (clays can retain more nutrients than sands)
- Moisture status: well-structured clays can store much more plant-available water than a sand (Figure 5).
- Infiltration (faster into a sand than a clay)



| Soil texture | Field Capacity | Permanent Wilting Point | Plant Available Water Content |
|---|---|---|---|
| Well-structured clay | 500 | 300 | 200 |
| Clay | 380 | 240 | 140 |
| Loam | 340 | 120 | 220 |
| Sandy loam | 230 | 90 | 140 |
| Sand | 90 | 20 | 70 |

**Figure 5. Ability of different soils to store plant-available water (mm water to 1 metre of depth)**

***Soil structure*** depends on how well the soil particles hold together in peds. Peds are the building blocks of soil. Soil structure depends on:

- Texture - clay particles are better at forming peds
- Type of nutrients in soil, eg, calcium promotes ped formation while sodium causes dispersion
- Organic matter: the major factor promoting good soil structure

Soil structure affects:

- Water movement into and through the soil (the better the structure, the greater the 'porosity': the volume of soil not occupied by solid particles)
- Aeration of soils: well-structured soils provide more oxygen to plant roots

Nitrogen (N) and phosphorus (P) are the critical nutrients on most grazing lands. Soil nutrients are concentrated in the topsoil, and their content in soil declines sharply with depth.

***Organic matter in soil*** is accumulated as partially-decayed plant and animal tissue. It is continually being broken down and replenished. Organic matter is critical because it:

- Retains nutrients
- Supplies nutrients (N, P, sulphur (S))
- Improves moisture-holding capacity
- Stimulates soil organisms
- Improves soil structure
- Buffers changes in pH

***Soil organisms*** include invertebrate animals (eg, earthworms, beetles, termites) and microbes (bacteria and fungi). These organisms are critical for breakdown of organic material such as plant litter (Figure 6) and for mineralisation (release of nutrients in a form that is available for plants). Earthworms are common only in wetter, milder environments. Termites are more important in the drier, more infertile environments. Many soil fungi form relationships (mycorrhizas) with plant roots, aiding nutrient and water uptake.

**Figure 6. The soil teems with organisms that break down organic material and release nutrients.** The picture on the left shows a magnified image of a nematode, which uses a stylet to pierce plant cells. The picture on the right shows underground termites, which can do a similar job to earthworms in improving water entry and nutrient cycling.

***Soil pH*** is a measure of the soil's alkalinity or acidity. The pH ranges on a scale from 1 to 14 - the lower the pH value, the more acidic the soil. Soil with a pH of 7 is considered neutral; below 7 indicates an acid soil; above 7 indicates an alkaline soil. Note that on the pH scale, a pH of 6 is 10 times more acidic then a pH of 7. The availability of nutrients for plants changes with changes in pH. Nutrients are most available to plants in soils with pH values between 6 and 8. Plant growth can suffer if a soil becomes highly acid.

Soil supporting one land type will be able to grow more or less forage than soil on another land type, depending on all the characteristics mentioned above. However, productivity of all land types is enhanced by good soil condition. Management that encourages high plant cover and high litter input into soil will stimulate soil organisms, leading to better soil condition. Conversely, poor management of plant cover reduces soil organic matter, reducing soil structure and the activity of soil organisms; this will reduce both the quantity and quality of pasture for cattle.

### *2.2.4 Climate*

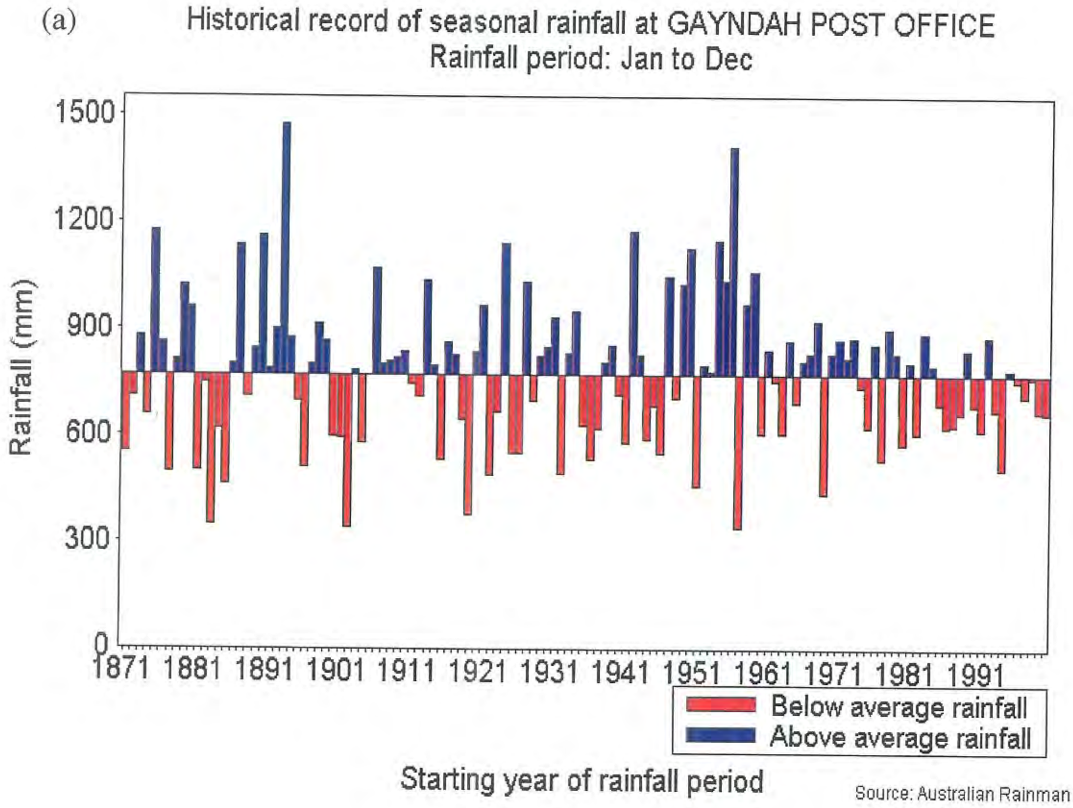
The interaction between soil, plants, and animals on grazing lands is influenced strongly by climate. Individual experience of the climate at a particular location forms perceptions about when to expect useful rain for forage growth and the likelihood of either not meeting, or of exceeding, these expectations.

For every property, variation in the incidence and amount of rainfall from year to year is a key driver of both productivity and risk. Appreciating longer-term variation in rainfall (over the past 100 years) helps broaden perceptions about climate and encourages a more deliberate approach to managing for variation (Figure 7 shows an example at one site).

In some regions, seasonal forecasts based on the southern oscillation index (SOI, related to variation in air pressure and in sea surface temperature (SST)) improve the odds of correctly anticipating the amount of useful rain. Figure 8 shows the relationship between sea surface temperatures in June and the likelihood of below-average, average or above-average pasture growth in the subsequent wet season. This is based on historical analysis of Charters Towers rainfall: for example, of the years that have had warmer than normal SST in June, 70% of these had above-average pasture growth in the subsequent wet season. This contrasts with those years when SST has been cooler than normal in June, with only 6% of these years having above-average pasture growth.

A modified forecast system, based on longer-term variations in sea surface temperatures, promises more accurate forecasts and better anticipation of "runs" of drier or wetter years. This new system, called SPOTA-1, uses an index called the Norfolk-Hawaii Index (NHI), in addition to the SOI, to provide a useful forecast in April in most years. The reliability of the forecasts then improves between April and October, thus providing forecasts with improved timeliness and reliability compared to current systems.

(a)




(b)

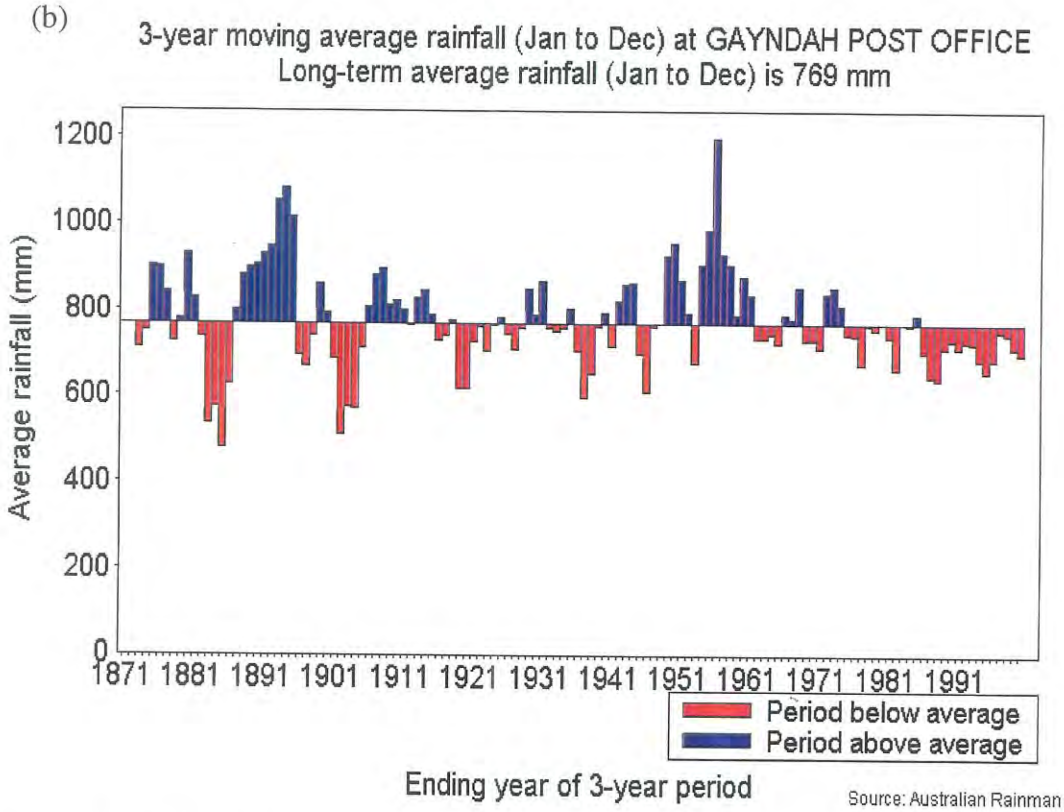



**Figure. 7. The historical variation in rainfall at Gaydah for both annual rainfall (a) and the 3-year moving average (b).**

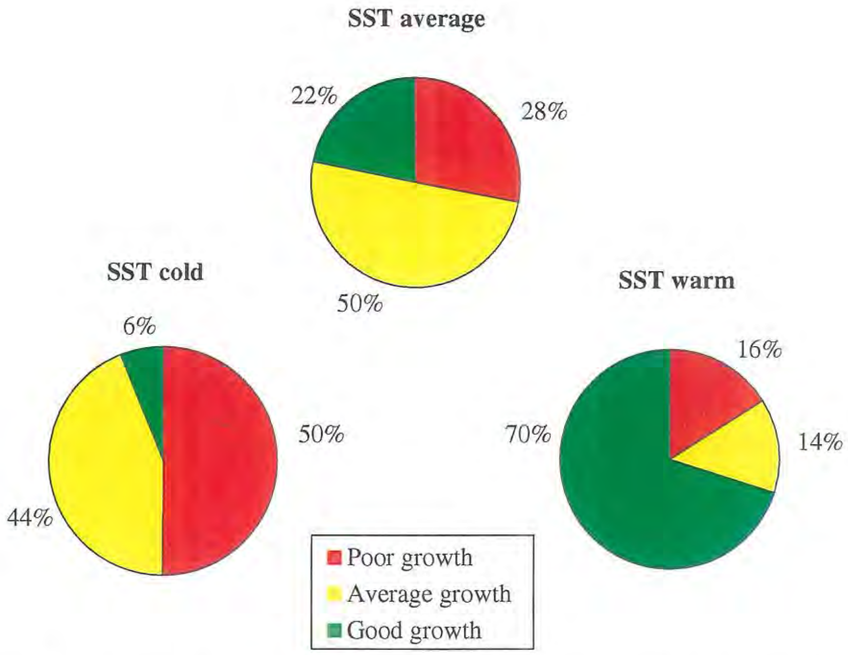



**Figure. 8. How sea surface temperatures (SST) in winter affect the chances of good pasture growth in the subsequent growing season for grazing lands in Dalrymple Shire.**

In the tropics, the distinct wet/dry pattern of pasture growth during the year is primarily related to the pattern in available soil moisture. In the subtropics, the pattern of growth is still biased towards summer growth but is not as distinct as further north. Soil moisture drives summer growth in the subtropics but temperature limits response to any winter rain and influences the start of the growing season (Figure 9).

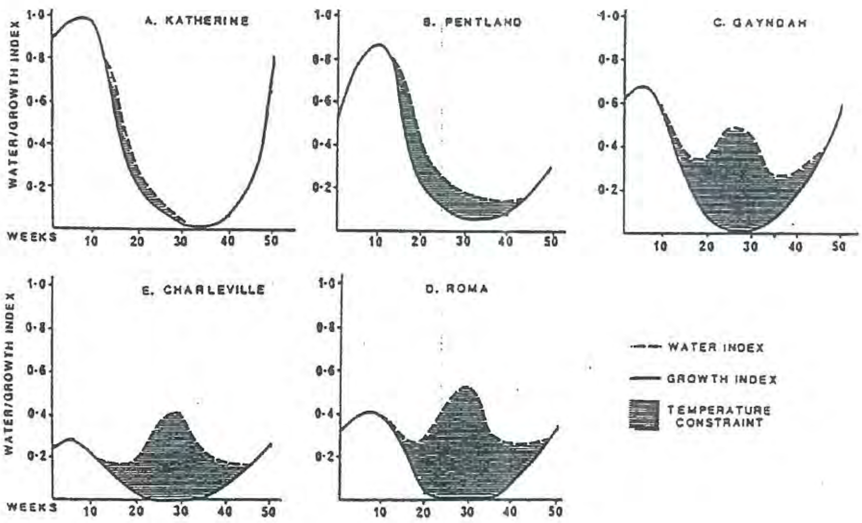



**Figure 9. The relative importance of soil water and temperature in constraining pasture growth throughout the year at various sites in the tropics and sub-tropics.** Note that the x-axis is week of the year (1-52), commencing in January.

Global warming is often in the news, due to concern over the consequences of increased levels of carbon dioxide and other chemicals in the atmosphere. Average temperature across the globe increased over the 20th century by 0.6$^0$C. The average surface temperature is predicted to increase by between 1.4 to 5.8$^0$ over the period 1990 to 2100. Probable consequences include greater risk of droughts and floods, especially in regions affected by the southern oscillation.

### *2.2.5 Classifying and mapping ecosystems and land types*

***Conservation mapping:*** To assist with planning of conservation, Australia was recently mapped into 80 broad bioregions: these are meant to be 'natural regions', based on broad landscape patterns. These bioregions tend to represent the major patterns in geology and climate (Fig. 10).

Within the broad bioregions, there has been some division into 'regional ecosystems'. The information used to map regional ecosystems varies, but they tend to represent an amalgamation of land types/systems. They are being used to assess the conservation status of vegetation types in Queensland (the so-called vegetation management process) and therefore are used in the permit process for tree clearing applications. Regional ecosystem mapping is generally too broad for use as the basis of management planning for grazing lands.

***Land type mapping:*** We will use a "grazing land type" (or land type) as the basis for mapping, inventory, assessment and planning for grazing land management. The criterion for distinguishing land types within a paddock or property is that different land types produce different amounts or types of vegetation. Therefore, if the land type covers a significant area of the paddock, these differences are likely to affect productivity and/or influence management options.

Grazing land types correspond to land types or soil units as mapped in resource surveys. Often, the particular land type is not physically mapped but, rather, the mapping is based on either land systems or soil associations. Land systems are areas throughout which can be seen a recurring pattern of topography, soils and vegetation. Both land system and soil association maps usually have additional information about the likely mix of land types or soils present in a particular mapping unit.

The mapping available for each region will have a slightly different approach to distinguishing land types; most will have land system or soil association mapping at a nominated scale. Most areas will not have detailed mapping of land units.

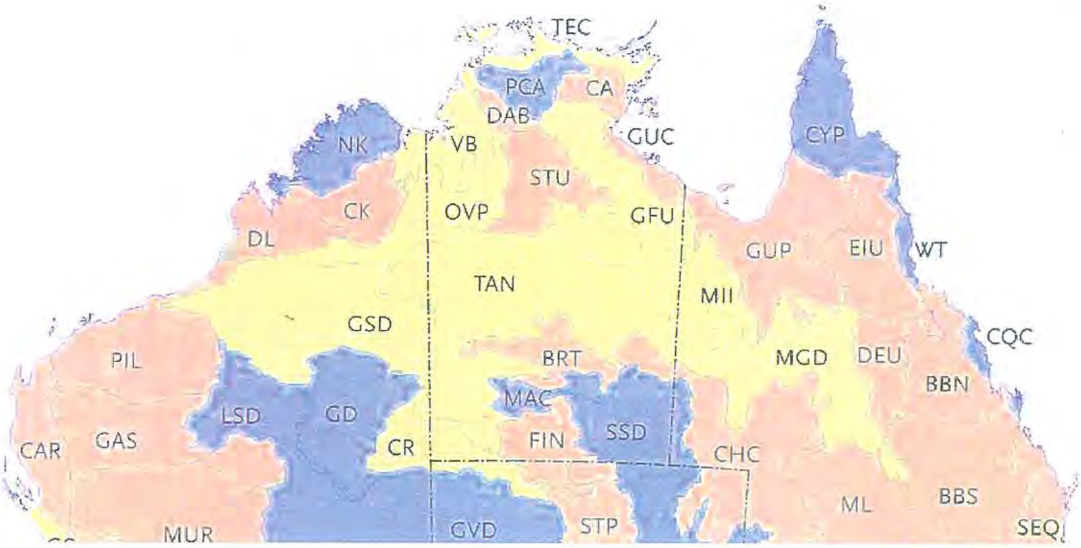



**Figure 10. The bioregional ecosystems of North Australia**

**Key:**

| | | |
|---|---|---|
| BBN - Brigalow Belt North | BBS - Brigalow Belt South | BRT - Burt Plain |
| CA - Central Arnhem | CAR - Carnarvon | CHC - Channel Country |
| CQC - Central Q'land Coast | CR - Central Ranges | CYP - Cape York Peninsula |
| DAB - Daly Basin | DEU - Desert Uplands | DL - Dampierland |
| EIU - Einasleigh Uplands | FIN - Finke | GAS - Gascoyne |
| GFU - Gulf fall & Uplands | GSD - Great Sandy Desert | GUC - Gulf Coastal |
| LSD - Little Sandy Desert | MAC - MacDonnell Ranges | MGD - Mitchell Grass Downs MII - Mt Isa Inlier |
| ML - Mulga Lands | NK - North Kimberley | |
| OVP - Ord-Victoria Plains | PCA - Pine Creek - Arnhem | PIL - Pilbara |
| SEQ - South-east Qld | SSD - Simpson - Strzelecki Dunefields | |
| STU - Sturt Plateau | TAN - Tanami Desert | TEC - Top End Coastal |
| VB - Victoria - Bonaparte | WT - Wet tropics | |

## 2.3 How do grazing land ecosystems work?

Key ecological processes link all the soil, plants, animals, and atmosphere of a grazing land ecosystem: energy flow, nutrient cycling and water cycling. These processes are also inter-linked. Maintaining these processes is the key to maintaining good condition grazing lands.

### *2.3.1 Energy flow*

Grazing lands are driven by energy from the sun. Plants can make direct use of the sun's energy via photosynthesis. Photosynthesis is the process by which plants convert light energy into chemical energy, stored in the form of carbohydrate (sugars), using carbon dioxide from the air and water from the soil:

| Carbon dioxide + water + sun's energy → Carbohydrate (sugars) + oxygen |
|---|

This is referred to as the "equation of life" because all life on earth is ultimately dependent on this capture of solar energy.

Chlorophyll is the green pigment in leaves that traps the sun's energy. Plants take in carbon dioxide through pores (stomata) in their leaves, losing water (transpiration) and oxygen from the leaf at the same time.

Plant growth is driven by photosynthesis. Therefore, the greater the area of green leaf in a pasture, the greater the forage production that can be expected. The capture of energy via photosynthesis, and the use of this energy to produce complex carbohydrates (starch, cellulose), proteins, and other compounds in the plant, requires mineral nutrients like nitrogen, phosphorus, potassium, sulphur, magnesium and others. For example, nitrogen is a major component of protein and makes up about 16% of a protein molecule. These minerals, and water, are absorbed from the soil by the plant's root system.

Plants are called "primary producers", since they make their own food. This food energy flows through a food chain (Figure 11): the energy captured by plants flows to either herbivores (cattle, sheep, kangaroos, grasshoppers) or to decomposers (earthworms, beetles, bacteria, fungi). The energy flowing to herbivores will then flow to either carnivores or to decomposers. The energy captured by carnivores eventually flows to decomposers. The decomposers break down the organic material to smaller and smaller bits, until all that remains is the chemical components.

Energy flows, it does not cycle: energy is lost at each step in the food chain (Figure 11) as plants, animals, and microbes use (respire) energy to maintain themselves. Usually, less than 10% of the energy from one step or level in the food chain is transferred to the next level. Thus, energy is steadily drained from the grazing land ecosystem and the ecosystem will not continue to function unless plants continue to capture energy from the sun.

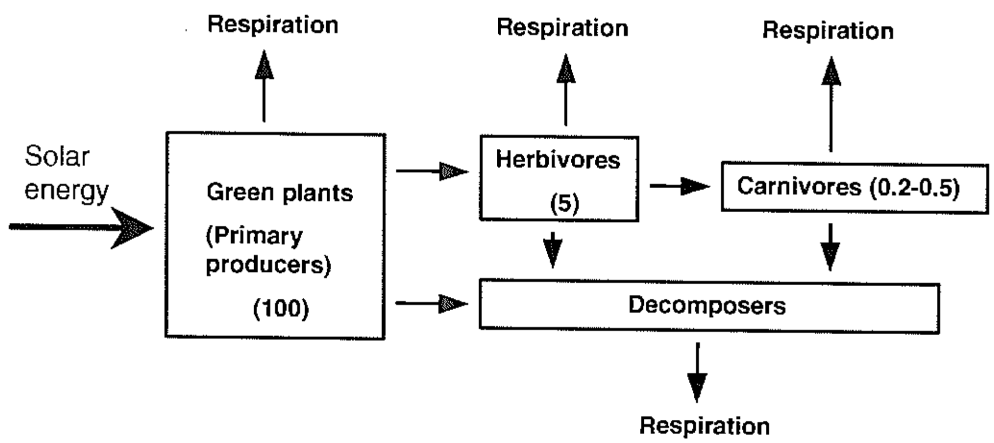



**Figure 11. The flow of energy through an ecosystem.** This model shows the possible fate of 100 units of energy captured in pasture. Note the losses in energy at each step in the food chain, steadily draining the energy captured by plants.

Good land condition is associated with a dense coverage of perennial grasses, guaranteeing efficient capture of solar energy (pasture growth represents capture of solar energy). If perennial grasses are in decline, then less energy is captured and less energy will flow through the food chain. Hence, less energy will be available for grazing animals and there will be less organic matter returning to the soil. Soil condition declines, further restricting the capture of energy. Therefore, if perennial grasses decline, the process of energy capture will gradually wind down.

Figure 12 shows what happens when perennial grasses decline in response to persistent overgrazing. The pasture growth from 4 adjacent areas was measured, each area representing either, good, moderate, fair, or poor condition, based largely on density of perennial grasses.

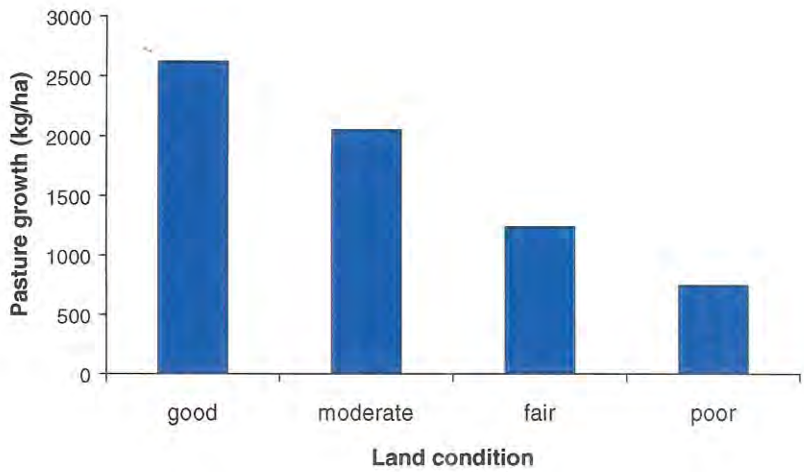



**Figure 12. The decline in energy capture (pasture growth) in pastures in which perennial grasses have been grazed out compared to good condition pastures.**

### *2.3.2 Nutrient cycling*

Plants and animals cannot function without essential nutrients such as nitrogen (N) and phosphorus (P). For example, plants cannot grow without access to N. N is required to make proteins, and proteins are needed for photosynthesis and other metabolic processes.

Nutrients such as N are cycled through the ecosystem; thus, unlike energy, nutrients can be reused. Without effective cycling of nutrients their supply would soon be exhausted, as there is a limited supply of nutrients in any soil.

Nutrients are taken up by plants, and then may be returned to the soil directly via plant litter, or may cycle through herbivores and/or carnivores before returning to the soil as animal waste or carcass. The nutrients become part of the organic matter in the soil, and can then be cycled by soil organisms (Figure 13). The larger soil organisms break down the organic material into small particles, and the bacteria and fungi release (mineralise) the nutrients in mineral form. Nutrients must get to this mineral form to be available, once more, for plant uptake.

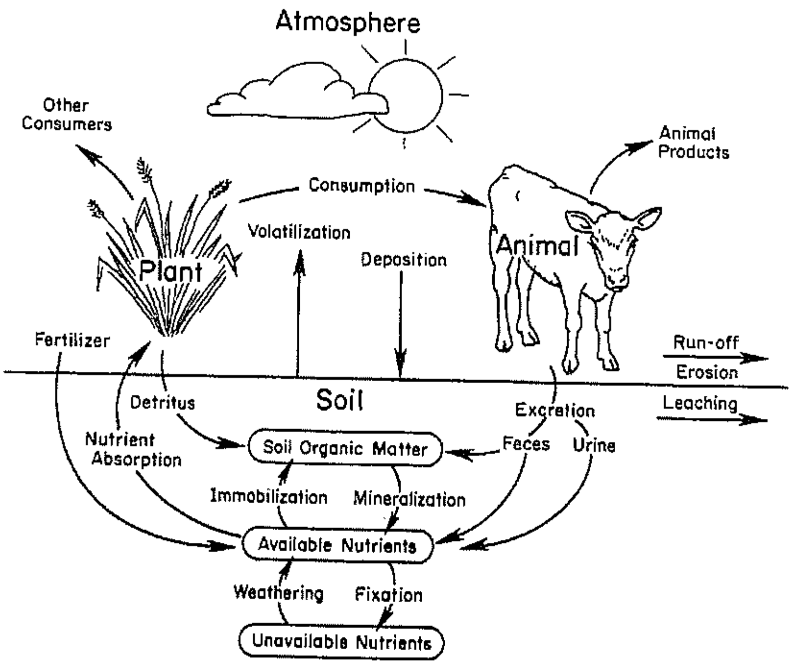



**Figure 13. Nutrient cycling within grazing land ecosystems**

Nutrient cycling is never perfect, and any significant losses must be balanced by gains if the ecosystem is not to run down. In well-managed grazing lands, both the losses from the ecosystem and the gains from outside the ecosystem are small compared to the amounts cycling within. Only small amounts of nutrients are lost in animal products. Even fire causes only small losses of nutrients (mainly N), which are usually offset by nutrient input from rainfall. This contrasts with cropping systems where large quantities of nutrients are removed during harvest, and need to be replaced by fertilisers.

Nutrient cycling is greatly affected by vegetation cover and organic matter:

- low plant cover means that less solar energy is captured so that less energy flows through to decomposers, soil organic matter declines, and there is poor release of nutrients for plant growth (note linkage to energy flow)
- low plant cover increases the risk of increased runoff and erosion, which will cause a net loss of nutrients (note linkage to water cycle)
- the rate of cycling increases with the nutrient content of the organic matter.

Good land condition is associated with little or no loss of nutrients from the grazing land ecosystem, with high levels of soil organic matter, and high levels of soil biological activity. Where perennial grasses decline, there will be less organic matter in the soil, less activity from soil organisms, and therefore a decline in nutrient cycling. Also, poor ground cover will allow loss of nutrients in run-off. Soluble nutrients such as nitrogen, sulphur and potassium can be lost in surface run-off, along with nutrients that attach to clay particles, like phosphorus and calcium. Thus, loss of perennial grasses will see a decline in nutrient cycling and the risk of a net loss of nutrients from the ecosystem. This, in turn, will limit energy capture in plants.

Figure 14 shows how perennial tussock grasses are the key to maintaining biological activity and nutrient cycling . High levels of soil organic matter are associated with high levels of biological activity. Soil organic matter (measured as soil carbon) is concentrated in the vicinity of healthy tussocks, with very little soil organic matter in bare patches. In the former areas, nutrients and water are conserved and may also be enriched by run-off from adjacent bare areas. Also, soil condition is enhanced by the biological activity of the perennial grasses themselves (from root growth and litter input).

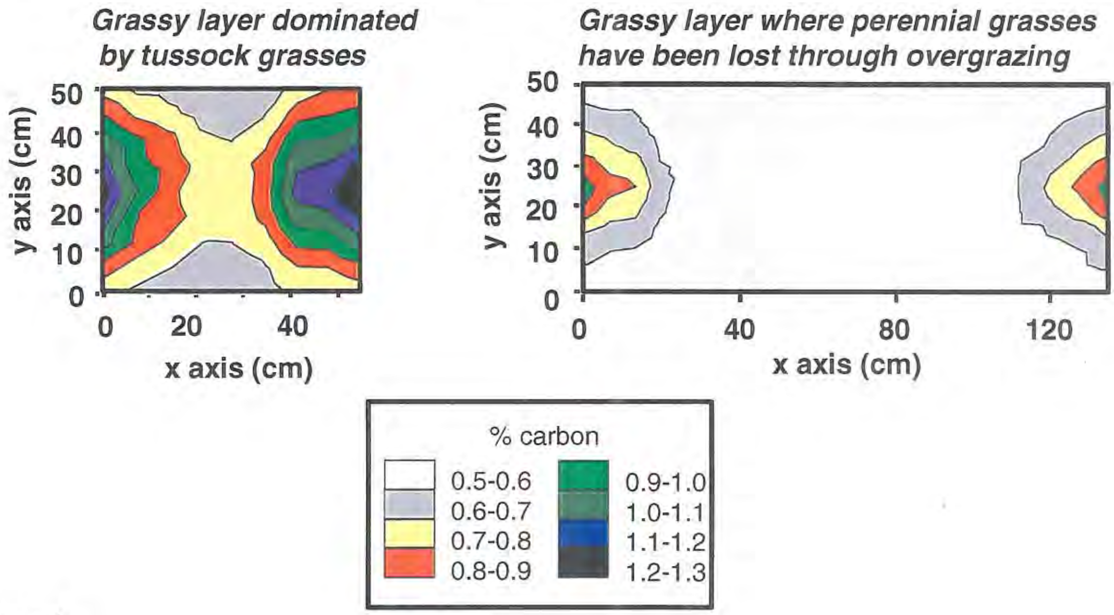



**Figure 14. The amounts and distribution of soil organic matter in pastures having good coverage of grass tussocks compared with pastures having sparse coverage of tussocks.**

### *2.3.3 Water cycling*

According to Leonardo da Vinci, "water is the driving force of nature". Water is the medium in which nutrients cycle, water is an essential component of plant and animal cells, and water (as rainfall) is a potentially erosive force. Maintaining a healthy water cycle is therefore critical for productive grazing lands.

The water cycle (Figure 15) describes water movement through the environment:

- Rainfall is the major source of water inflow to soil
- Infiltration is water movement into soil
- Surface run-off is rainfall that doesn't enter the soil and runs off onto other country or into drainage lines
- Transpiration is water drawn through plants from soil via their roots, and that is eventually lost to the atmosphere through their leaves
- Evaporation is water vapour lost from soil or from surface water into the atmosphere.

With grazing land in good condition, infiltration is maximised and run-off is minimised, so that we get the most efficient use of rainfall for pasture growth (measured as rainfall use efficiency: RUE). Soil condition, ground-cover and density of perennial grasses determine the health of the water cycle.

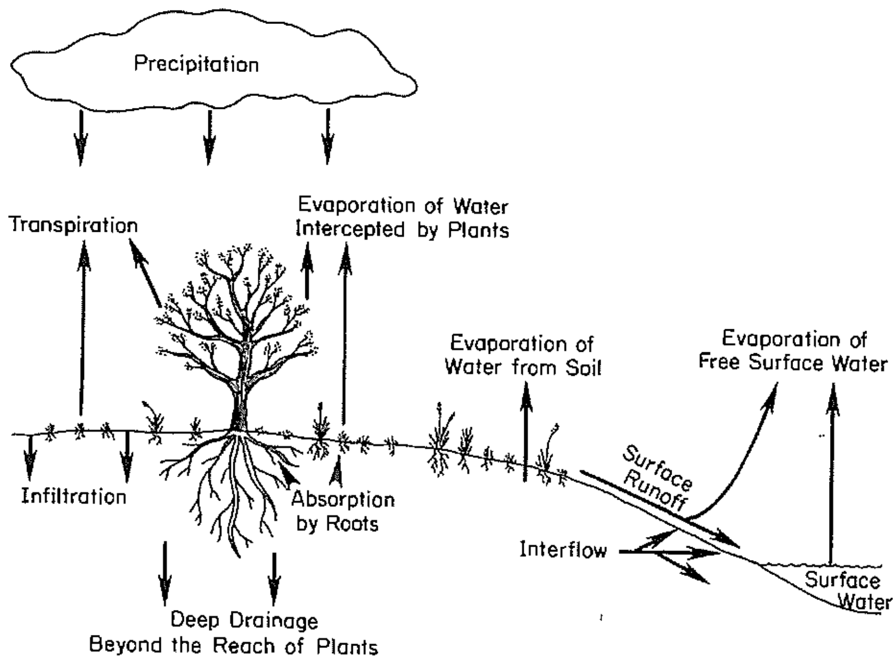



**Figure 15. The water cycle in grazing lands**

There is a fundamental difference in the implications of a poor nutrient cycle and a poor water cycle. Nutrients such as N, P and S are largely cycled on site (interacting with the atmosphere) whereas major parts of the water cycle are off-site: in aquifers, streams and oceans. Thus, a poor water cycle will not necessarily exhaust the supply of water for that site into the future, whereas poor nutrient cycling will eventually deplete the soil reserves.

This does not mean that the penalties of a poor water cycle are trivial; in fact they have the potential to severely and permanently disrupt the ecosystem. Penalties from a poor water cycle (poor infiltration, high run-off and erosion) include:

- lost opportunities to use water for forage growth (note link to energy flow), which reduces carrying capacity and produces self-inflicted forage droughts;
- increased losses of nutrients and soil (note link to nutrient cycling), which may eventually desolate the ecosystem.

Figure 16 shows average rates of run-off and soil loss plotted against the amount of ground cover (% of ground covered by plant material). Up to 40-50% of annual rainfall can be lost as run-off in poor condition pastures, effectively reducing rainfall to only half of what actually falls (Figure 17)

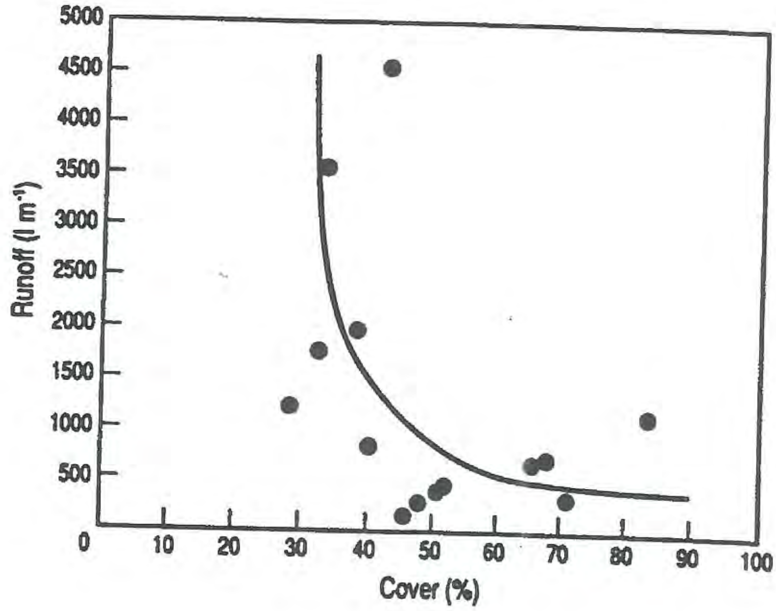



**Figure 16. Relationship between run-off of rainwater and ground cover**

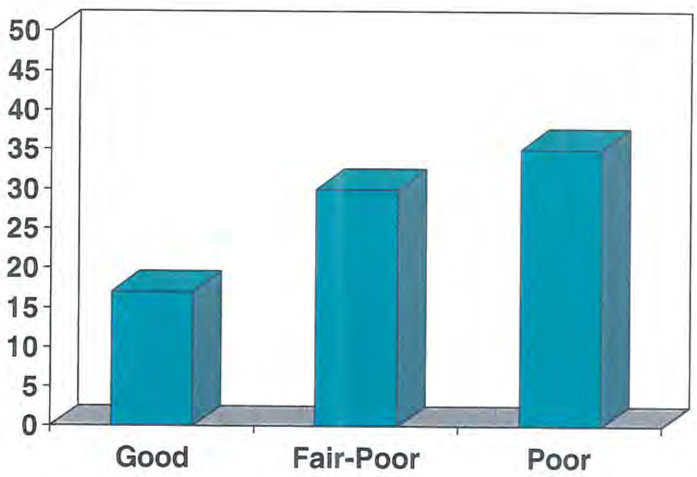



**Figure 17. Amount of runoff (%) from land in different condition classes in black speargrass country of the inland Burnett.**

Good land condition is associated with:

- Reduced run-off and low erosion risk: high plant cover minimises run-off and the risk of erosion, and maximises the chances of water being used for plant growth
- High infiltration rate: good soil structure maximises infiltration which also helps minimise runoff and erosion, and maximises water use by plants
- Any run-off water is of high quality: water that has very low concentrations of sediment and nutrients.

### *2.3.4 Productivity and stability: dependent on land condition*

The carrying capacity of grazing land is dependent on its ability to produce forage, that is, its land condition. Land condition, in turn, is a measure of how well the grazing land is capturing energy, cycling nutrients and using water. The productivity of grazing lands can, therefore, be measured by the amount of forage grown. Of course, animal productivity from grazing lands also depends on the quality of the forage that is grown.

Production of forage varies from land type to land type and from year to year. Variation in forage production is driven by variation in the:

- Supply of resources (light, water, nutrients): productivity is only as great as the most limiting factor. Soil moisture often limits forage production, as does availability of soil nitrogen.
- Capture of resources: dependent on density and persistence of plant cover (annual vs perennial grasses), and on the length of the growing season (depends on rainfall, nutrient availability and temperature)
- Conversion of resources: plants differ in their ability to use resources and produce useful forage, eg, there are differences between perennials and annuals, leafy grasses and stemmy grasses, grasses and trees.

So, this variation in the capture of solar energy into forage is related to:

- factors beyond direct or immediate control of management, eg. rainfall, land type;
- factors that are heavily dependent on management (plant cover and type, water use, nutrient cycling).

Stability of a grazing land ecosystem is also related to land condition. Stability is a grazing land's ability to persist and retain or recover function in the face of disruption from factors like drought, wild-fire, overgrazing, or infestation by pests or disease. One land type will be more or less stable than another depending on:

- Its inherent soil fertility and structure: more fertile land types tend to be more stable;
- The local climate: stability declines with increasing aridity and/or increasing variability of rainfall;
- Its evolutionary history: grazing lands in Australia have not evolved with either continuous or intermittent periods of moderate grazing, in contrast to the grasslands of Africa and north America;
- The tendency for woody plants to increase or invade: most grazing lands have a tendency towards woodiness which, historically, has been checked by regular fires.

Importantly, the stability of every land type can be enhanced by:

- Encouraging good land condition: effects of variability and disruption are magnified as land declines in condition
- Not pushing land so hard that it passes a "point of no return" (or threshold), beyond which recovery is slow or minimal
- Promoting diversity in vegetation: grazing lands dominated by only 1 or 2 species are more susceptible to disruption from disease, drought etc than grazing lands with a greater mix of forage species and plant types.

## 2.4 How do we measure how well a grazing land ecosystem is working?

Land condition is the capacity of grazing land to produce useful forage; it is about productivity and sustainability. It is a measure of how well the grazing land ecosystem is working, that is, how well solar energy is being captured, how well nutrients are being cycled, and how well rainfall is being used. Land condition is therefore directly related to carrying capacity.

### *2.4.1 Classifying land condition*

Land condition can be classified into 4 broad categories:

1. Good or "A" condition (Figure 18): has all the following features
   - Good coverage of perennial grasses dominated by the those species considered to be 3P grasses for that land type; little bare ground (<30%);
   - Few weeds and no significant infestations;
   - Good soil condition: no erosion, good surface condition;
   - No sign, or only early signs, of woodland thickening.

**Figure 18. Land in 'A', or good, condition.**

2. Fair or "B" condition (Figure 19): has at least 1 or more of the following features, otherwise similar to A condition
   - Some decline of 3P grasses; increase in other species (less favoured grasses, weeds) and/or bare ground (>30% but <60%);
   - Some decline in soil condition; some signs of previous erosion and/or current susceptibility to erosion is a concern;
   - Some thickening in density of woody plants

**Figure 19. Land in 'B', or fair, condition**

3. Poor or "C" condition (Figure 20): has 1 or more of the following features, otherwise similar to B condition
   - General decline of 3P grasses; large amounts of less favoured species and/or bare ground (>60%)
   - Obvious signs of past erosion and/or susceptibility currently high
   - General thickening in density of woody plants.

**Figure 20. Land in 'C', or poor, condition**

4. Very poor or "D" condition (Figure 21): has 1 or more of the following features:
   - General lack of any perennial grasses or forbs
   - Severe erosion or scalding, resulting in hostile environment for plant growth
   - Thickets of woody plants cover most of area

**Figure 21. Land in 'D', or very poor, condition**

On any land type, each of the condition categories may be represented by more than one form or 'state'. For example, condition 'A' land may be represented by different mixes of 3P grasses (including exotics). Similarly, condition 'D' land may be represented by lack of 3P grasses, or by high density of woody plants, or by extensive loss of soil condition. The four broad condition categories provide a means of ranking these 'states' with respect to their ability to grow useful forage.

***2.4.2 Indicators of land condition***

There are 7 main indicators of land condition;

- Density and coverage of 3P grasses
- Levels of ground-cover
- Condition of the surface soil
- Evidence of erosion
- Presence of weeds
- Woodland condition

***Density and coverage of 3P grasses (perennial, productive, palatable):***

3P grasses are the key to maintaining energy flow, nutrient cycling and effective water use. They capture energy efficiently and promote energy flow through both grazing animals and soil organisms. They keep moisture and nutrients in the paddock, on site, instead of these resources leaking away down slope. The 3P grasses also maintain soil organic matter, thereby stimulating soil organisms and promoting soil structure. Any decline in 3P grasses therefore threatens the condition of the land.

***Levels of ground-cover:***

Maintaining ground-cover above 50% is essential for minimising run-off and loss of nutrients and soil, and for promoting forage production. Low ground cover results in less solar energy being used by plants, loss of nutrients and top-soil, and poor water use.

*Condition of the surface soil:*
Good condition reflects healthy organic matter content and good soil structure which will enhance infiltration and biological activity. Compare the soil surface condition around a grass tussock compared to that in a bare or scalded area. Litter cover, and signs of incorporation of litter into the soil, indicate biological activity.

*Evidence of erosion:*
Top-soil represents most of the fertility and biological activity of soils; its loss causes severe and permanent disruption of the grazing land ecosystem. Signs vary with the form of erosion; these forms correspond with a progressive concentration of run-off. Inter-rill or sheet erosion is loss of thin layers or sheets of soil in each successive storm; it often goes unnoticed in early stages but will eventually show clear signs such as soil pedestals (Figure 22), and will eventually cause loss of all top-soil. As water concentrates into discrete flow paths, it forms rill erosion (Figure 23), seen as tiny gullies. As these rills widen and deepen, they form gully erosion.

Scalding is the result of massive loss of surface horizon soil in texture-contrast or duplex soils, exposing the lower horizon which is typically hard when dry and has very low infiltration rates (Figure 24).

**Figure 22. Pedestals, formed by removal of soil from around the roots of grass plants.**

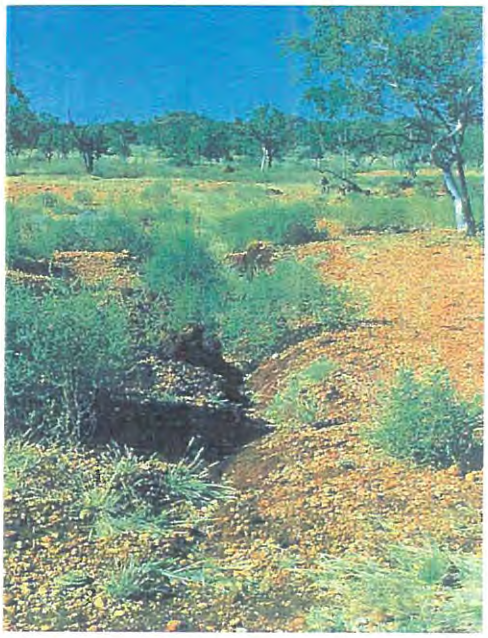


**Figure 23. Advanced rill erosion**

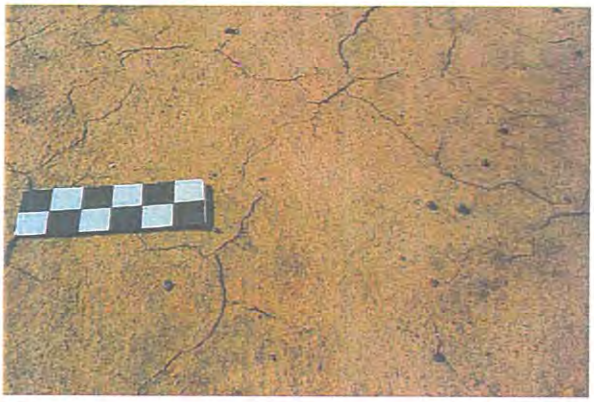


**Figure 24. Scalded surface**

***Presence of weeds:***
Weeds use light, nutrients and water that could otherwise be used for useful forage production. Some also hinder movement and others may be toxic to cattle. Weed infestations are often associated with declining land condition, as weeds are able to exploit disturbed and bare areas, taking advantage of reduced competition from pasture. Some weeds are also favoured by lack of fire in the grazing system.

***Woodland condition***
Woody plants use resources that could otherwise be directed towards forage production. Increased woodiness therefore reduces carrying capacity. Many grazing lands have a trend of increasing woodiness associated with lack of fire. Woody plants can stimulate the ecosystem by acting as nutrient pumps and reducing water loss via evaporation, but these stimulatory effects on pasture growth are usually overwhelmed by their competitive effects, especially as woody plant density increases.

On the other hand if woodlands are over-cleared, disruption of the water cycle may result in waterlogging and/or salinity. Overclearing also threatens diversity; this is often accentuated by an increased impact of die-back on remaining trees.

### *2.4.3 Tracking changes in land condition*

Tracking land condition also requires an understanding of the susceptibility of country to change and the likelihood of any changes being reversed. Grazing is implicated in most changes in land condition, but other factors are often involved including fire (or lack of), tree clearing, sowing pastures, and weed invasion.

As shown in Figure 25, the susceptibility of land to a change in condition, and the ease with which changes can be reversed, is dependent on land condition. Land in condition 'A' is relatively stable. Also, land that is trending towards 'B' can be fairly quickly reverted to 'A' by a change in management. However, land in condition 'B" is susceptible to a quick decline to 'C'. Also, reversing this change may require a major change in management and will take some time to occur. Land in 'C' is very susceptible to falling rapidly to condition 'D'. Land in 'D' will not revert to 'C' by simply changing management, at least not in any time frame of practical interest to grazing land management. Reverting land in 'D' to 'C' requires a large input of external energy (eg, mechanical, chemical), and even this may be insufficient if soil condition has been severely reduced.

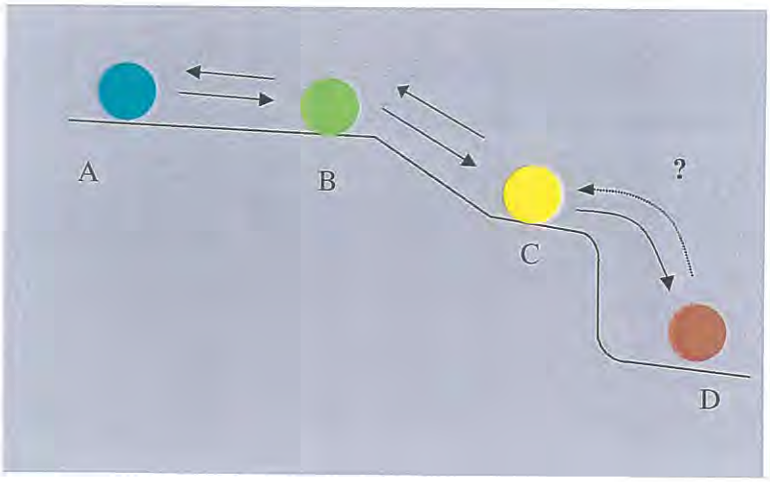



**Figure 25. Not all changes in land condition occur at the same rate and some are not easily reversible.**

It is also important to distinguish cosmetic changes in land condition from real changes. For example, well-managed grazing land in condition A may appear to change to condition B during a run of dry years, but in reality maintains a good density of perennial plants and quickly resumes the "classic" look of A condition with one good wet season. Another common misreading of condition is that land in condition C is "OK" because it manages to produce green cover during a run of wet years. The reality is that perennial grass density remains low and that, even with some recovery of perennial grasses, soil organic matter and biological activity take much longer to recover.

A useful way of summarising the possible changes in land condition is to use a box and arrow diagram, with the boxes representing the condition of land at a particular time and the arrows indicating how changes in land condition can occur. For example, we could use 4 boxes to represent A, B, C, and D land condition (as defined above), and draw in arrows to indicate:

- What circumstances will lead to a change from one state to the next;
- How easily or quickly these changes occur;
- When changes are not readily reversible.

Each of the condition categories may be represented by more than one vegetation structure and composition. For example, condition C might be represented by a loss of perennial grasses, or by heavy weed infestation, or by excessive density of woody plants. This is the basis of so-called 'State and Transition' models or diagrams, which ecologists and land managers can use to build up an understanding of the various 'states' (defined as a distinct vegetation structure and composition) and the triggers that lead to change (or 'transition') in 'state'.

***Assessing and recording land condition***

Many signs of land condition can be noted during normal property operations such as mustering and water runs. For example, observations could include the abundance of various pasture plants, the amount of cover, the presence of weeds, the amount of woody plant regrowth, the health of trees, the condition of the soil, and signs of erosion. These observations should be recorded for future reference, such as in a diary or in a book set aside specifically for recording land condition.

There can be benefits from adding to these "on-the-run" observations of land condition with a more structured monitoring program such as GrassCheck or similar methods. These advantages include:

- Greater reliability - observations are repeated at the one site, providing a more reliable guide to trend in condition. Memories tend to be unreliable. Also, any procedure that encourages the operator to look into the pasture, rather than looking over it, will give a more reliable and comprehensive view of how the ecosystem is working.
- More information and insights - for example, a series of photos can provide insights into trend in woodland condition and variation in ground cover. Also, several indicators can be recorded for the one site, giving a comprehensive assessment of land condition (soil, pasture and woodland)
- More focussed - a structured monitoring program needs planning, encouraging a more deliberate approach and requiring the operator to define what they want from the system. It is more likely, therefore, to pinpoint the indicators of land condition of most interest.

The monitoring program should:

- follow sound guidelines for locating monitoring sites,
- select the measurement procedures (photos, quadrat estimates) that will deliver what is required for management purposes, for example, taking photos will not satisfy a need for information on pasture and soil condition.

At each monitoring site, the following measurements are recommended:

- presence/absence of 3P grasses: using 'quadrats' located along the monitoring site

- ground-cover: estimate using photo-standards
- photos: from fixed sites over time to show change in woodland condition and weeds

**Using information on land condition**

Knowing the current status of land condition in a paddock (ie, knowing whether land types within a paddock are in A, B, or C condition) allows a more realistic assessment of carrying capacity. It also identifies problem areas, or potential problem areas. This, in turn, helps identify opportunities to improve land condition, using the tools of grazing management, fire, woodland management, sown pastures and weed control.

On-going assessments of land condition (every 1-3 years) help identify the trend, providing useful feedback on the effectiveness of the management strategy being implemented. Sorting out the effect of climate on trend, versus that of management, is essential. Rainfall variability will cause indicators of land condition to vary up or down, and it is important to avoid the trap of interpreting all good news as due to management and all bad news as due to rainfall! It is recommended to have a couple of monitoring sites located in an area that is always lightly grazed, eg, distant from water. These sites will show the strength and direction of any variation in land condition that is due to mainly to climate, and will help isolate the actual trend being caused by management.

### *2.4.4 Financial consequences of land condition*

We have seen how land condition effects the key processes in grazing ecosystems. How we manage land condition also has major and on-going effects on the financial return from a grazing enterprise. For example, Table 3 shows an evaluation of the financial implications for a 20,000 ha property of having an overall land condition of either 'A' or 'C'. Based on the assumptions that:

- 'C' condition country grows 40% less pasture than 'A' condition
- 'C' condition country provides lower forage quality which drops intake by 5%
- the property is stocked with steers at a 'safe' carrying capacity (based on an average consumption of 25% of annual forage growth).

Note that there is a substantial penalty in both revenue potential and return on investment for land in 'C' condition.

**Table 3. Financial implications of having a property in 'A' condition versus 'C' condition (steers only; stocked at safe carrying capacity).**

| | 'A' condition | 'B' condition |
|---|---|---|
| Carrying capacity (head) | 3625 | 2290 |
| Weight gain (kg/head/year) | 140 | 110 |
| Net revenue at sale ($/head) | 1.15 | 1.15 |
| Direct costs ($/head/year) | 40 | 40 |
| Overhead costs ($/year) | 150,000 | 150,000 |
| **Profit before tax ($/year)** | **292,000** | **44,100** |

## 2.5 How do we manage land condition to enhance production and sustainability?

Grazing land management is about optimising energy flow, nutrient cycling and water cycling using the tools of grazing, fire, woodland management, sown pastures and weed control. These tools are used to:

- Direct the type and amount of plant cover, the use of water, and the cycling of nutrients;
- Anticipate and respond to variation in rainfall, land type and land condition;
- Build stability through land condition and diversity.

The GLM workshop covers each of these tools, showing how to use them to achieve your goals for land condition and productivity.

# 3. MANAGING GRAZING

## 3.1 Why is grazing management so important?

Lack of attention to grazing management is the cause of common problems on grazing lands, such as:

- decline of better pasture plants and increased incidence of less desirable ones;
- forage supply out of balance with forage demand, with cattle not meeting production targets and signs of declining land condition;
- uncertainty about how to manage stocking rates;
- excessive soil loss and decline in soil health;
- inadequate use and management of fire; and
- uneven use of pasture, with some areas of paddocks grazed out and other areas hardly touched.

Managing grazing is the most critical factor in grazing land management. It is the major means by which we control the production and use of forage. If control is inadequate, then there is little chance of meeting these goals.

Better grazing management works through all 3 gateways towards sustainable beef production:

- **Rainfall use efficiency**: improving land condition (eg, encouraging the better pasture plants with wet season spelling) increases forage growth per mm of rainfall received, thereby improving carrying capacity and decreasing susceptibility to drought;
- **Pasture utilisation**: optimising level and evenness of pasture use (eg, optimising paddock design; flexible stocking rate management) increases the amount of forage consumed by livestock and, thereby, carrying capacity;
- **Conversion efficiency**: improving diet quality (eg, providing adequate opportunity for selective grazing) improves the conversion of forage to beef, thereby helping to meet production targets.

Most effects of grazing management are through its effects on *utilisation* of pasture. In fact, grazing management is largely about controlling the timing, amount, and evenness of pasture use.

To help achieve better grazing management, we will cover:

- how to balance forage growth and forage use so that land condition is improved;
- how to assess pasture quality and quantity;
- how to assess animal demand for forage, including the effects of management and supplementation;
- how to optimise water point distribution and paddock design; and
- how to manage stocking rates to reach production and land condition targets.

There are no recipes or silver bullet technologies that will most efficiently and effectively meet the needs of every situation, eg, a particular grazing method or forage budgeting tool. Instead, there is a systematic process that analyses your current situation, and helps evaluate options for improving both production and sustainability.

### *3.1.1 Assessing long-term carrying capacity: a way of analysing the current grazing system*

The GLM workshop demonstrates a procedure for assessing long-term carrying capacity (CC) of a paddock. Long-term CC is defined as the average number of animals that a paddock can be expected to support over a planning horizon (5-10 years), given:

- the current mix of land types;
- the condition of these land types
- the climate;
- the evenness of use by cattle;
- the grazing strategy or method; and
- the goals for animal production and land condition

The procedure is based on balancing the expected forage production with forage use: estimates of average forage production for a paddock are converted to long-term carrying capacity with the appropriate safe utilisation level.

This procedure provides a benchmark of "where we are at now". It helps identify options for improving the grazing strategy, and also quantifies the likely benefits, at least in terms of increased carrying capacity. The financial consequences of different options can then be compared with the tools used in the GLM workshop. This procedure helps identify the grazing strategy that will best meet production and sustainability goals.

Note that the carrying capacity procedure is not about recommending the number of animals that should be run at any specific time. This requires consideration of the short-term carrying capacity.

### *3.1.2 Short-term carrying capacity*

Short-term carrying capacity is the number of animals that a paddock can support for a week, a month, a season or a year. Short-term CC will deviate from long-term carrying capacity due to variation in rainfall received. It is a function of pasture on hand and anticipated pasture growth, but also depends on forage quality and desired animal performance.

Long-term and short-term CC are strongly related. The perception of long-term CC will affect the average number of animals run, so will affect the frequency of forage imbalances (between supply and demand). An unduly optimistic perception of long-term CC leads to chronic problems with forage balance and acute problems with land condition.

Conversely, the approach to managing short-term CC affects long-term CC. If there is limited adjustment of stock numbers in response to changes in forage supply, then long-term CC will need to be relatively low (to reduce the frequency of forage imbalances). If stock numbers are adjusted 1-2 times a year to ensure forage balance, then the long-term CC can be enhanced. Thus, closer management of stock numbers in relation to short-term CC is one option for improving long-term CC.

### *3.1.3 Utilisation: a fundamental concept in grazing management*

The major challenge for grazing management is in balancing how much forage is grown with how much forage is eaten, so as to optimise production on a sustained basis. The pasture utilisation level determines this balance. Annual pasture utilisation is the proportion of annual pasture growth that is consumed by herbivores. Utilisation is directly related to grazing pressure: as utilisation increases, grazing pressure increases.

A high utilisation level can provide a short-term boost to production per unit area but at the expense of rainfall use efficiency and conversion efficiency. A low utilisation level promotes rainfall use efficiency and conversion efficiency, but at the expense of production per unit area.

Safe utilisation is the maximum rate of average annual use consistent with maintaining or encouraging good land condition, eg, a safe average utilisation level for a particular land type may be 25%, which means that grazing should be managed such that the average level of pasture utilisation is 25%. Recommended utilisation values usually assume that there is little effect of either distance from water or preferred use of land types on the evenness of forage use (as most guidelines are derived from small paddocks).

Safe utilisation levels will vary with:

- land type: some land types are more stable under grazing than others;
- grazing strategy: the utilisation level may be increased above the safe "average" value when there is regular spelling of pasture during the growing season;
- evenness of forage use, with respect to both:
    - evenness across a paddock: safe utilisation will decline with increasing unevenness of use
    - evenness of use from year to year: safe utilisation level will be higher where there is more active management of animal numbers in response to changes in forage supply (as long as utilisation doesn't 'blow out' in drier years).

### *3.1.4 Grazing management and biodiversity*

Grazing management can have major effects on biodiversity. Maintaining healthy land condition contributes to conservation of soil organisms and native plants and animals. However, species vary in their response to grazing (Figure 1). Some species are increasers (eg, wire grasses, galahs) and others are decreasers (kangaroo grass, some finches). Some species are very sensitive to grazing. Helping to conserve these species requires deliberate planning for areas of land that will receive little or no grazing. In some regions this can be done by limiting development of water points, so that there is some country more than 8 km from water. In other environments, it requires fencing off areas from grazing. The size of the area required will vary with the nature of the animals and plants that are being conserved.

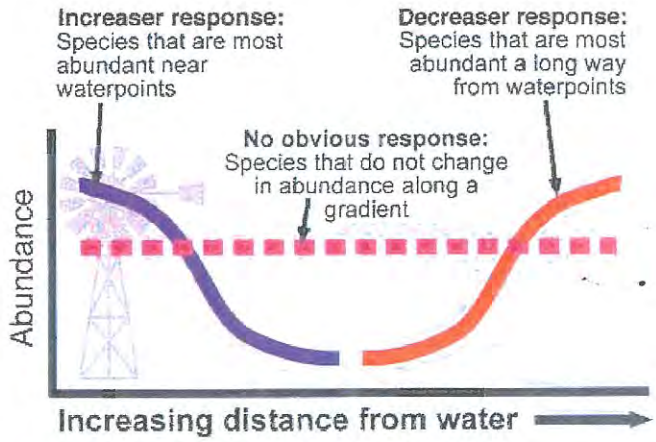



**Figure 1. General relationships between species abundance and grazing pressure (as indicated by distance from water).**

## 3.2 How can grazing management improve land condition?

Managing utilisation is the key to improving land condition. Grazing management should achieve a utilisation level that promotes the 3P (perennial, palatable and productive) grasses. Excessive utilisation has both short-term and long-term effects on RUE and land condition:

- short-term: excessive use on a once-off or irregular basis reduces the amount of pasture growth, due to reduction in leaf area and root growth (Figure 2)
  - ➔ short-term reduction in RUE (for 1-2 growing seasons) but may be little or no effect on land condition if over-use is not consistent.

**Figure 2. The effect of overuse during one growing season on root growth of a perennial grass.**

- long-term: excessive use on a consistent basis reduces the vigour of preferred species, which decline in the pasture, and are replaced by bare ground and /or less desirable species

  → loss of land condition and a persistent reduction in RUE.

Table 1 shows an example of these long-term effects of consistent over-use. Paddocks that started in 'B' condition were grazed at either 25% or 75% annual utilisation. The growth and abundance of the 3P grass, desert bluegrass, declined under consistent overuse (75% annual use), whereas it increased under 25% annual use. Note also that utilisation is the key to improving land condition. Table 1 shows the improvement in land condition for a paddock that started in condition 'C' and was subsequently managed for 25% annual utilisation. This improvement in condition occurred despite a run of drought years.

**Table 1. Effect of consistent over-use of pasture on land condition.** Table shows average standing crop and frequency of desert bluegrass (*Bothriochloa ewartiana*), a 3P grass, in native pasture in the goldfields country south-east of Charters Towers. Paddocks were in either good or poor condition in 1993, and were subsequently grazed at low (25%) or high (75%) annual utilisation rates. Note that 1993-96 were drought years.

| Measurement | Initial land condition | Utilisation (% of annual growth) | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|
| Standing crop (kg/ha) | 'B' | 25 | 753 | 517 | 964 | 998 | 946 | 1015 |
| | 'B' | 75 | 613 | 272 | 254 | 163 | 80 | 75 |
| | 'C' | 25 | 48 | 70 | 104 | 182 | 340 | 612 |
| Frequency (%) | 'B' | 25 | 40 | 38 | 53 | 48 | 50 | 61 |
| (a measure of abundance) | 'B' | 75 | 26 | 25 | 21 | 16 | 10 | 10 |
| | 'C' | 25 | 10 | 11 | 10 | 13 | 15 | 17 |

Effective management of utilisation is based on:

- Accounting for the effect of land type, land condition and climate on pasture growth and long-term carrying capacity
- Accounting for the effects of animal number, type and management on forage intake
- Coping with year-to year variation in short-term carrying capacity
- Timing pasture-spelling to greatest advantage

### *3.2.1 Accounting for effects of land type, land condition and climate on long-term carrying capacity*

Pasture growth is a product of photosynthesis, so is dependent on:

- the density of grass plants: the higher the density, the higher the green leaf area, and the greater the interception and capture of solar energy;
- the supply of water and nutrients: soil water and soil fertility work together to control pasture growth. Pasture growth in drier environments (<600 mm average annual rainfall) is commonly limited by water supply, while pasture

growth in wetter environments can be limited by both soil fertility and water supply. Soil available nitrogen is the key nutrient.

- environmental conditions, such as temperature, influence pasture growth in some environments.

These factors are responsible for the variation in pasture growth that we observe on different land types, on land in different condition categories, and from one year to the next. How do these factors influence pasture growth?

- pasture growth on different land types varies (Figure 3) mainly due to differences in the soil's ability to store moisture and provide nutrients, particularly nitrogen.
- pasture growth declines as land condition declines (Figure 4) due to loss of green leaf cover of desirable species, poor water use, and poor nutrient cycling. Variability of pasture growth increases as land condition declines.
- pasture growth varies from year to year largely due to variation in the amount and incidence of rainfall (Figure 5). While pasture growth obviously increases with annual rainfall, the relationship is not a simple one. The soil moisture available for plant growth is the net balance between inputs (rainfall, surface run-on) and outputs (surface run-off, soil evaporation, deep drainage). Also, the use of soil moisture for plant growth depends on land condition and the growth stage of the pasture. Hence not every mm of rainfall has the same impact on plant growth.

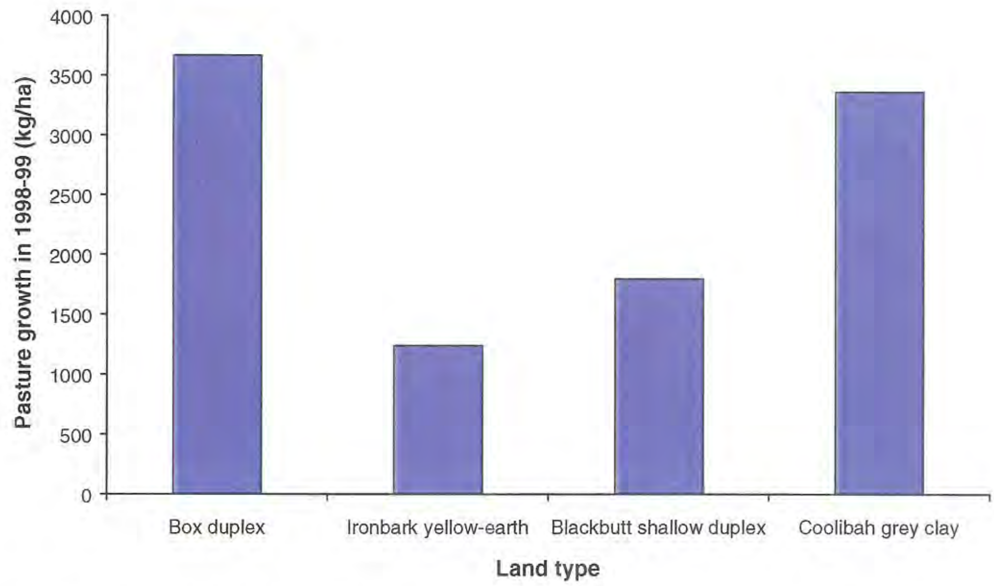



**Figure 3. An example of the effect of land type on pasture growth from the Charters Towers district.**

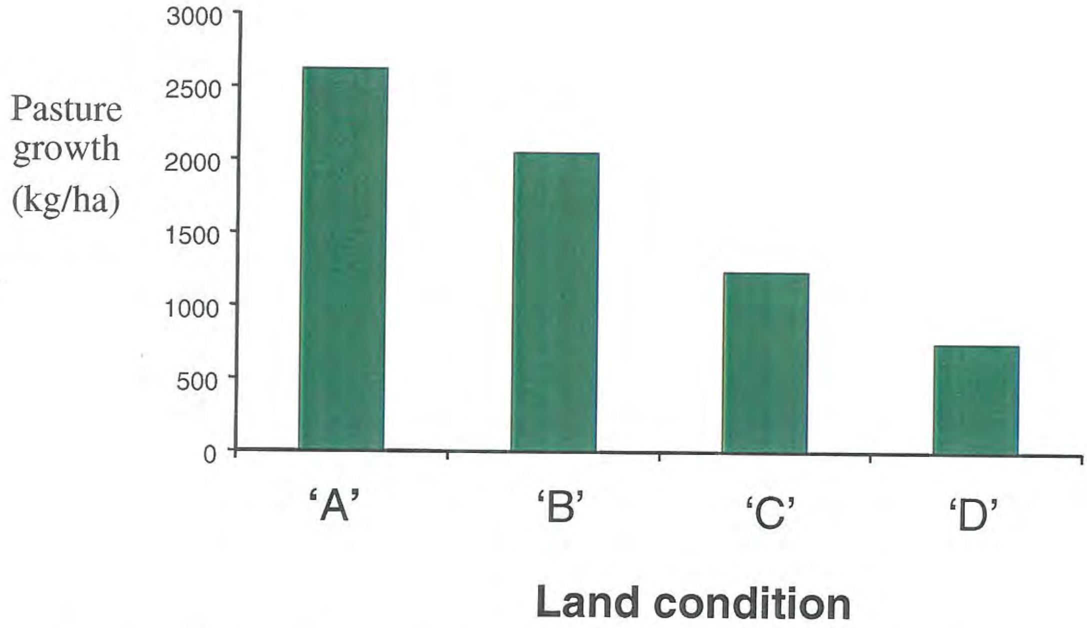



**Figure 4. Effect of land condition on annual pasture growth; data from Goldfields country south-east of Charters Towers.**

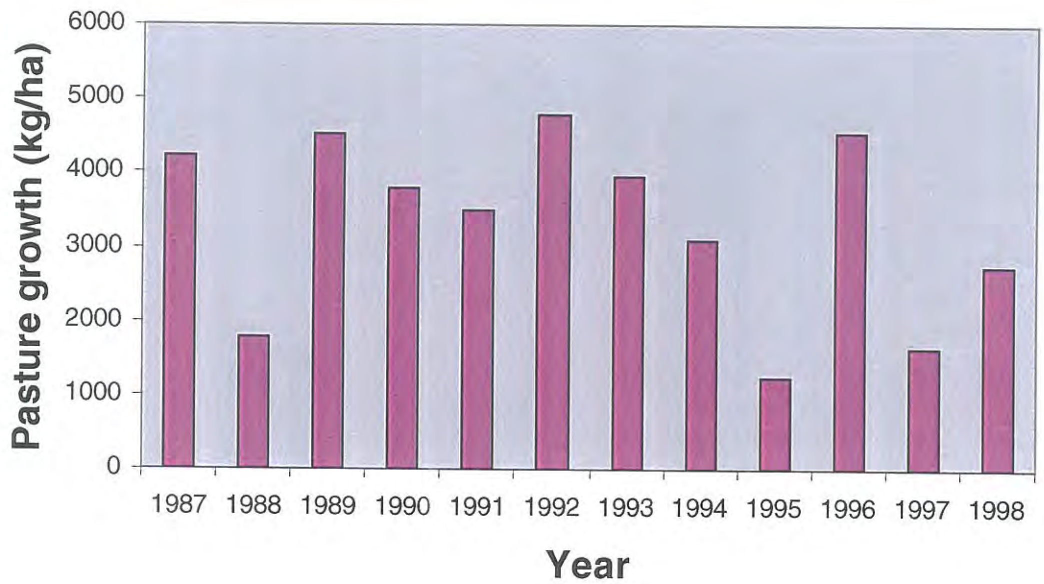



**Figure 5. Effect of rainfall variation on annual pasture growth; 12 years of data from silver-leaved ironbark country near Gayndah.**

A grass growth calculator, called GRASP, accounts for all these factors, providing estimates of pasture growth for different situations. It uses information on land type, land condition and historical rainfall records to provide:

- estimates of average grass production, as well as the likelihood or probability of receiving various amounts of pasture growth.

- forage production profiles: plots showing the pasture growth for all years within the rainfall records.
- the effect of the Southern Oscillation Index (SOI) and other indices (such as the Norfolk-Hawaii Index (NHI)) on the expectations for pasture growth.

GRASP provides the pasture production values on which we can base calculation of long-term carrying capacities.

As land type and land condition have large effects on pasture growth, these factors must be accounted for during assessment of long-term CC. Failure to account for these factors will result in pasture utilisation levels that are either wasteful of forage or, more likely, detrimental to land condition and diet quality.

Estimating areas of different land types in paddocks, and their condition (rated as A, B, C, or D), is the first step in the inventory procedure that leads to a realistic assessment of long-term CC. Information on the average pasture growth from land types in your region, for each land condition category, is available. These pasture production values, in combination with a 'safe' utilisation level and the annual forage demand per animal unit, are used to calculate long-term CC.

### *3.2.2 Accounting for the effects of animal number, type and management on forage intake*

Managing utilisation requires knowledge of both likely forage supply and likely forage demand. Animal number is obviously the major factor affecting demand for forage but animal intake is affected by several factors.

- Effect of animal type: accounting for the differences in intake due to type of animal (eg, cattle versus sheep), breed of animal (where mature size differs significantly), and class of animal (eg, breeding cows versus steers). The adult equivalent (AE) concept is a handy way of doing this. An AE is defined as the intake of a certain type of animal (we will use a 450 kg steer) and intakes of other animals are expressed as a proportion of this (Table 2).

**Table 2. Adult equivalent (AE) ratings for different classes and weights of animals.** Note that the liveweight expected for different ages and types of cattle will vary with country type and weight at maturity.

| Category | Adult Equivalent Rating | Average Liveweight (kg) |
|---|---|---|
| Pregnancy & Calves (< 6 months) | 0.35 | 120 |
| FEMALES | | |
| Weaners (Up to 18 months) | 0.50 | 200 |
| Heifers (18-30 months) | 0.75 | 300 |
| Dry Cows (>30 months) | 1.00 | 450 |
| MALES | | |
| Weaners (Up to 18 months) | 0.50 | 210 |
| 2 year old (18-30 months) | 0.80 | 330 |
| 3 year old (30-42 months) | **1.00** | **450** |
| 4 year old (42-54 months) | 1.20 | 600 |
| Bulls | 1.50 | 650+ |
| HORSES | 1.20 | |
| KANGAROOS | 0.10 | |

- Supplementation: supplementation with nitrogen (N) and phosphorus (P), or with small amounts of protein supplement (eg, cottonseed meal) can increase intake. N supplements improve intake during the dry season by about 15% on average. This effect on intake should be accounted for in managing short-term CC but has little effect on long-term CC. While supplements are often implicated as a 'cause' of over-grazing, it is total animal numbers rather than intake per head that has the overriding influence on trend in land condition. On P-deficient country, P supplements restore intake to expected levels so that there is no need to build in a factor for P when calculating AE's. Large amounts of protein supplements, or any amount of energy supplement (eg, grain, hay) reduces intake of pasture ('substitution' effect).

- Herd management: the management of mating, weaning and turn-off may affect both total forage intake and the pattern of this intake through the year.

- Total grazing pressure: native and feral herbivores (donkeys, camels, kangaroos, etc) can affect forage demand in some areas, adding to the utilisation of pasture. If significant, their number and intake per head should be estimated so that carrying capacity can be adjusted accordingly.

- Forage quality: forage quality is an obvious factor determining the amount and pattern of intake. A typical pattern is for forage intake to be highest in the first half of the growing season and then to decline to lowest levels in the winter or late dry season. Short term and sudden fluctuations in intake are associated with small falls of rain, frosts etc. An estimate of average daily intake is adequate for calculating long-term CC, but any large variations in forage quality and intake due to season should be included in estimates of short-term CC.

Both long-term and short-term carrying capacities will be calculated as either area of land in ha required per adult equivalent (AE), eg, 6 ha per AE, or as number of AE's per square kilometre (or 100 ha), eg, 15 AE per $km^2$. The current stocking rate in each paddock can be calculated by calculating the number of animals in each class (based on type and weight) and using the appropriate conversion factor to convert to adult equivalents (AE's).

### *3.2.3 Coping with year-to-year variation in short-term carrying capacity*

Managing for a particular pasture utilisation level must consider the large year-to-year variation in rainfall, which produces variation in short-term CC. Where stocking rate is varied little from year to year, the average annual utilisation rate must be low enough (15-30%, depending on land type) so that any overuse in dry years is not excessive, and is compensated by underuse in wet years. This will result in a conservative estimate of long-term CC (which is based on average pasture growth and average long-term utilisation level).

There are 3 broad approaches to managing variation in short-term carrying capacity:

1. Conservative approach: this approach plans on having little variation in stock numbers over time, unless of course there is a series of very dry years which would result in excessive over-use. This approximates a 'set-stocking' approach, and the target average annual utilisation level must be relatively low (15-30%, depending on land type). This approach accepts that there will be periods of under-use, but that these are necessary to balance out periods of over-use.

2. Opportunistic approach: this approach plans on having a base number of animals that changes little over time but uses temporary stocking-up to take advantage of runs of wetter years. The base number of animals corresponds to 80-90% of long-term CC (based on a target annual utilisation level of 15-25%). Stocking up and down is based on monitoring of both land condition and forage supply, as well as consideration of the cattle market. This approach takes advantage of the fact that there are runs of good years, eg, where 3 out of 4 years are above-average. Of course, it must also plan for runs of below-average years: the ecological risk of this approach is that any periods of over-use may not be adequately balanced by periods of under-use.

3. Trading approach: this approach plans on adjusting stock numbers frequently (at least once per year) in line with variation in short-term carrying capacity. There may be a base number of animals that is retained where possible, but this base number will correspond to only a proportion (50-60%) of the long-term CC. This approach takes full advantage of periods of above-average forage supply but also avoids any periods of over-use. As such, it allows the targeted average annual utilisation level to be increased to 25-40%, depending on land type. This approach requires very active monitoring of land condition and forage supply plus a very active buying/selling policy. It will only suit enterprises where the dominant class of animal lends itself to frequent trading. The nature of beef production, the difficulties in anticipating forage supply, and the vagaries of the

market mean that this approach is difficult to implement and that it is risky both economically and ecologically. Economics will often conflict with ecological requirements, eg, where stocking down may be indicated but the market is unfavourable, thereby increasing the ecological risk as well. The timing and timeliness of adjustments in stock numbers is also critical. For example, stocking up may occur towards the latter half of an above-average growing season, but this may not be the appropriate number to run through the following growing season.

An example of the trading approach is:

- having a "base" group of animals (numbers of which vary little in most years), with its size set at about 60-70% of carrying capacity
- having a "trading" group of animals (usually dry stock; numbers vary with changes in forage supply), with its size initially set at 30-40% of carrying capacity
- forage budgeting for the dry season (done in March-May for the May to November period: based on achieving animal performance targets and maintaining ground cover; considers animal condition, forage available and forage quality
- forage budgeting for the wet season (done in September-November for the December to April period): based on achieving animal performance and land condition targets and forecast utilisation of 30-40%; considers seasonal outlooks, current land condition and current animal condition.
- trading group of animals adjusted to meet management objectives.

This approach requires careful monitoring of land condition, animal condition, forage supply and markets. Without such monitoring, the approach is risky both ecologically and economically.

All approaches to managing short-term variation in CC require regular assessment of the quantity and quality of forage on hand, as well as assessing the likelihood of additional forage growth. These estimates can used for a *forage budget*, ie, a comparison of the supply of forage (both existing and projected) with the demand for forage.

Assessing the amount of forage on offer requires practice, but photo-standards help train the eye (Figure 6 shows a couple of examples). When assessing the amount of available forage:

- discount forage which is distant from water (see later for discount factors) and
- do not include the yield of annual or unpalatable species.

Assessing forage quality is essential when feed budgeting if animal performance is to meet production targets. Similar amounts of pasture may have very different forage quality, depending on land type, growth phase and type of growing season. Visual appraisal is only adequate for discerning gross differences in forage quality and for indicating the availability of key forage species like legumes. Direct estimates of diet quality are provided by NIRS analysis of faecal samples (Figure 7 shows an example); the technology is in development phase and should be available for general use in the near future.

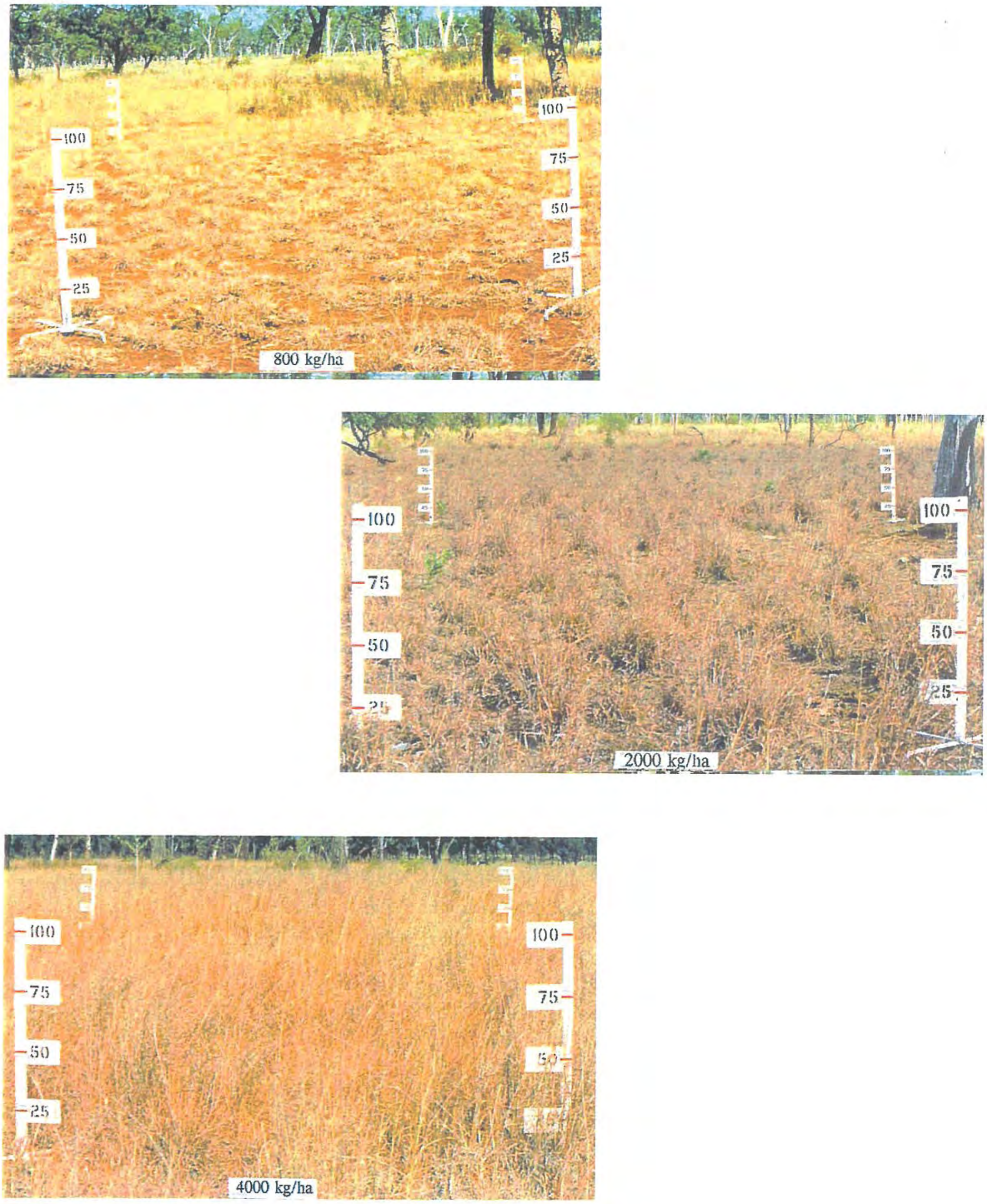



**Figure 6. Examples of photo-standards for use in forage budgeting**

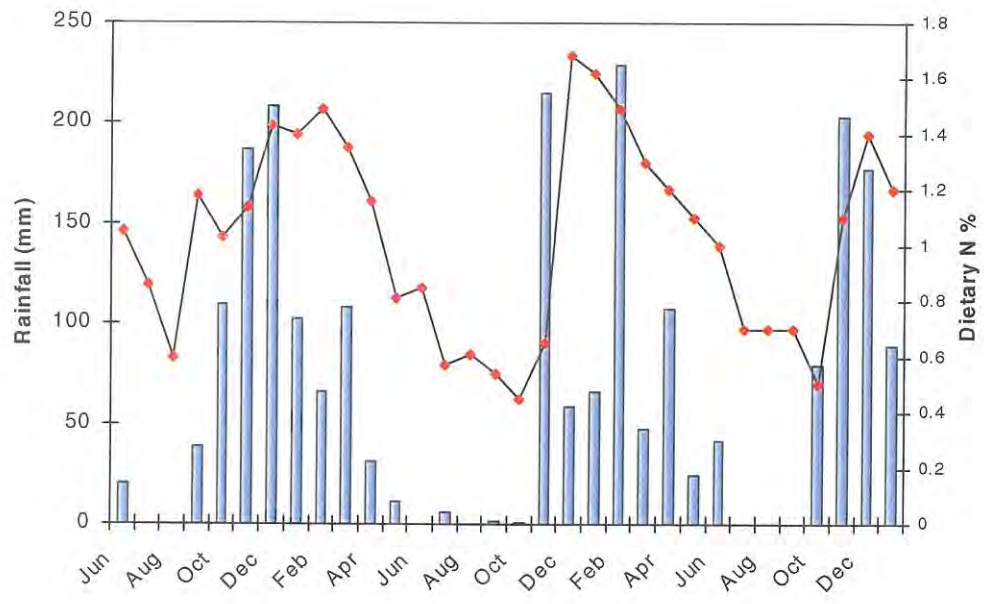



**Figure 7. Estimates of diet quality (N %, line graph), derived from NIRS analysis of faecal samples, plotted with rainfall (vertical bars) for Wambiana grazing trial from June 1998 to January 2001;** note that dietary crude protein is calculated as multiplying the N% by 6.25.

### *3.2.4 Timing of pasture-spelling*

The annual utilisation level measures the amount of pasture removed over 12 months compared to the amount grown over that time. It is a but useful measure of grazing pressure on grazing lands, but is a gross measure. The actual impact of pasture use, or grazing pressure, at any particular time depends on the growth stage of the pasture. The generalised pattern of pasture growth (Fig 8) during a year has 4 phases:

- **Phase 1**:
  - ➢ Short, leafy growth phase
  - ➢ Moderate pasture growth rate
  - ➢ High forage quality
  - ➢ Highly sensitivity to grazing pressure
- **Phase 2:**
  - ➢ Well-developed leafy tussock phase
  - ➢ High pasture growth rate
  - ➢ Good forage quality
  - ➢ Moderate sensitivity to grazing pressure
- **Phase 3:**
  - ➢ Reproductive phase
  - ➢ Low pasture growth rate
  - ➢ Moderate-low forage quality
  - ➢ Low-moderate sensitivity to grazing pressure
- **Phase 4:**
  - ➢ Dormant phase
  - ➢ Little or no growth
  - ➢ Low-very low forage quality
  - ➢ Low sensitivity to grazing pressure

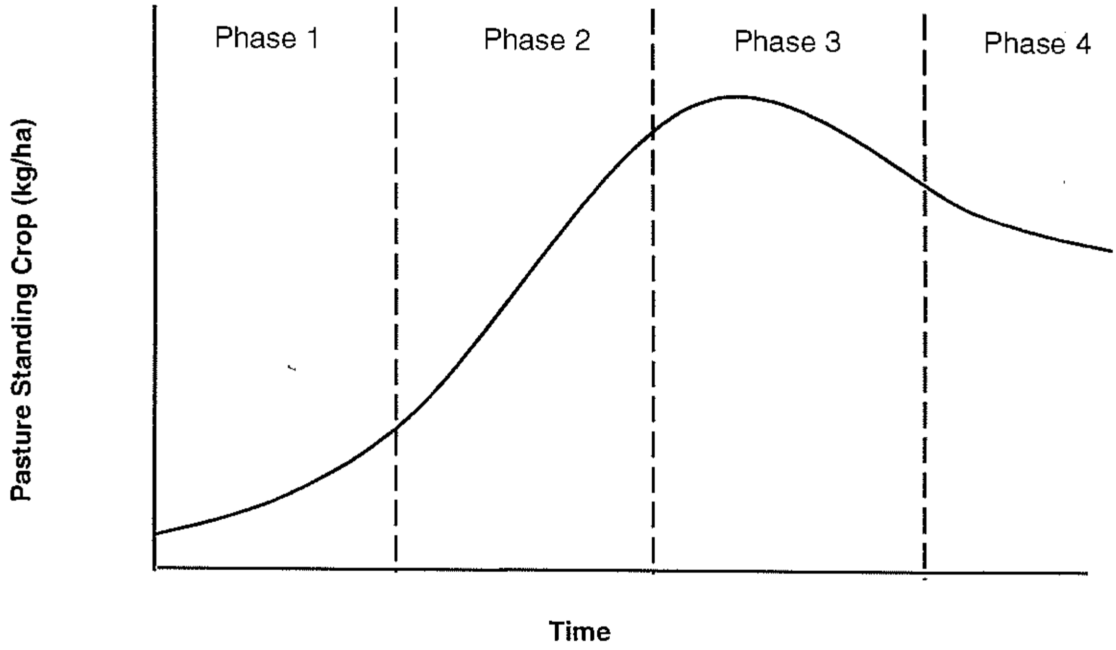



**Figure 8. The generalised pasture growth curve showing the four growth phases.**

The safe utilisation level for a pasture will be limited by the grazing pressure applied at the start of the growing season (Phase 1) because this is the time of greatest sensitivity to grazing.

It follows that carrying capacity of a pasture is limited by the grazing pressure applied at the start of the growing season. A grazing strategy based on continuous stocking will therefore have lower carrying capacity than a grazing strategy based on regular spelling (or rest) of pastures during Phase 1.

Spelling improves land condition, but is only effective if applied during the growing season. Regular wet season spelling (once every 2-4 years) accelerates recovery of land condition, leading to improvements in RUE and carrying capacity. Most benefit comes from rest during Phase 1, with somewhat less benefit from rest in Phases 2 and 3. Where pastures have low density of the 3P species, and/or these key species are short-lived, then there is extra benefit from rest in Phase 3 because of enhanced seed-set.

An example of a grazing strategy that includes wet-season spelling is one in which a large breeder paddock is sub-divided into 4 smaller paddocks, with each paddock receiving a wet season spell in turn, ie, each paddock is spelled 1 year in 4. It is important that paddocks in such a system have similar carrying capacities to avoid disproportionate grazing pressure on those paddocks not being spelled. Such a strategy increases carrying capacity by:

- permitting a higher safe utilisation level, and/or
- improving RUE and, therefore, pasture growth.

The generalised growth curve is a useful tool, but must be applied cautiously in extensive grazing lands. Unlike the high-rainfall temperate pastures where it was first applied, grazing lands in the northern half of Australia experience high variability in amount and incidence of rainfall. The actual growth pattern of pasture, and the length of each of the phases, will actually vary greatly from year to year in response to rainfall variability. The amount and incidence of rainfall dominates the actual pattern of the growth curve, ie, how long the pasture remains in each growth phase. At any one time, pastures will contain 2 or more growth stages and there is often mixing in the sward of new and old growth, and leaf and stem, making it difficult for animals to exclusively select green leaf.

Grazing management can ensure that the pasture does not stall in Phase 1, but it is difficult in the tropics and sub-tropics to manipulate pastures so that they prolong Phase 2, which is the best phase for animal performance. It may be possible to do so in years with an extended and even growing season, but it will require periods of high grazing pressure. This strategy will therefore incur a cost from reduced animal performance. This again is different to southern high-rainfall pastures where managers attempt to maintain pastures in Phase 2 for as long as possible through rotation and block-grazing techniques. This approach is more akin to that used on intensively-grown pastures like ryegrass where regrowth is guaranteed through either reliable rainfall, irrigation and/or use of fertiliser.

Progress along the growth curve can be slow (poor rainfall throughout the growing season) with an extended period in Phase 1, or fast (plenty of rain in a short time period) with little time in either Phase 1 or Phase 2 and most of the time in Phase 3. Growth may stall in one phase for short or long periods, depending on rainfall.

In addition, different grass species will progress through the phases at different rates. For example, some grasses like Queensland bluegrass tend to get to phase 3 early in the growing season, while others like black speargrass will tend to stay in phase 2 for longer (as its flowering is induced by shortening daylength).

Except for the dormant season, most paddocks will tend to be a mix of 'patches' (small uniform areas) representing 2 or more of these growth phases. This is caused by uneven use of the pasture and is characteristic of most grazing lands. Some patchiness is desirable for animal performance, but problems occur if patches persist in Phase 1 from one year to the next, as the persistent overuse will cause loss of grass cover.

### 3.3 How can grazing management improve the evenness of pasture use?

Recommended annual utilisation levels assume that there is relatively even use of pasture across a paddock. However, uneven use is characteristic of most grazing lands. Where there is chronic over-use or under-use of significant areas within a paddock, then the safe utilisation level for the whole paddock must be adjusted, which will reduce carrying capacity.

Uneven use of pasture across a paddock is most commonly due to 1 or more of the following:

- grazing gradients associated with distance to water
- animal preference for particular land types
- patch grazing
- animal preference for particular plant species

The last 3 factors are associated with selective grazing. Selective grazing is desirable: it is the behaviour that grazing animals have evolved for ensuring they get the highest diet quality possible from the mix of land types, plant species and plant parts on offer. Restricting selective grazing will therefore tend to restrict diet quality and animal performance. On the other hand, some control of selective grazing is required to ensure:

- efficient use of pasture across the mix of land types
- avoidance of persistent overgrazing of particular land types, patches or plant species, as this will cause a loss of land condition.

### *3.3.1 Managing distance to water*

There is a strong relationship between intensity of cattle grazing and distance to water. While cattle can walk up to 10 km from water, uneven use of forage can be evident even when distance to water is less than 2-3 km (Figure 9). While tis general relationship holds, it will vary with stocking rate (ie, at higher stocking rates, utilisation will be greater at a given distance to water) and paddock size. A clear gradient in grazing pressure away from water is common in large uniform paddocks (>3000ha). In smaller paddocks, the effect of distance from water interacts with preference for land type and simple gradients in grazing pressure away from water are less common. This does not imply that distance to water is not contributing to uneven use, only that the pattern of use in not simple.

The carrying capacity of a paddock must therefore account for distance from water. There is little point basing carrying capacity on pasture that is not being readily utilised. Otherwise, gross overuse and underuse of areas will develop, and both land condition and animal performance will not meet management goals. This correction of carrying capacity is done by determining the area of paddocks that lies within different distance intervals from water, and by applying the appropriate discount factor. The difference between the uncorrected and the corrected carrying capacity values show the potential benefit from improving water point distribution.

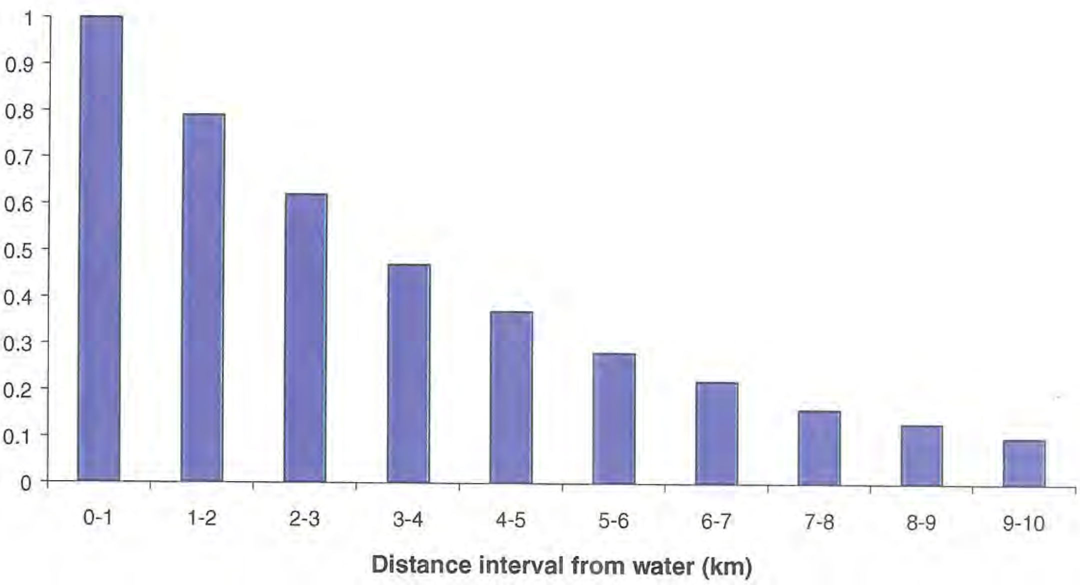



**Figure 9. Relative grazing pressure in relation to distance from water**

### *3.3.2 Managing animal preference for land types*

Preference for land types arises from animals attempting to maximise their nutrient intake. Given the variable nature of most paddocks, and the widespread occurrence of infertile soils, it is not unexpected that areas of more fertile soil (eg, riparian areas, pockets of deeper soil) tend to be overused (Figure 10) because they grow more and/or better quality forage.

**Figure 10. An example of selective over-use of a land type**

Where there is strong preference for particular land types, and these land types are of significant area, then carrying capacity should be reduced to conserve land condition. Alternatively, areas that are being either overused or avoided can be fenced off and managed separately.

Some mix of land types in paddocks is often considered desirable, particularly where paddocks are large and there is limited management of animals or pasture. Some variability in land type can enhance animal production, eg, having a mix of light and heavy soils captures the benefits of both lighter falls of rain and heavy falls. Similarly, a mix of country may allow animals to maintain better N and P status compared to relying on one land type alone. Splitting of paddocks may reduce their value as "safe" paddocks, ie, paddocks where cattle will perform OK regardless of rainfall intensity, frost or length of dry season. Put another way, splitting larger paddocks will require more attention to animal and pasture management. Of course, having more paddocks allows better management of land and animal, as well as increasing the evenness of use of pasture.

Other options for managing selective use of land types are:

- burning off under-used areas to attract cattle (Figure 11);
- spelling paddocks: spelling gives the whole paddock a rest, whereas reduced stocking rate often has little effect on use of preferred areas.

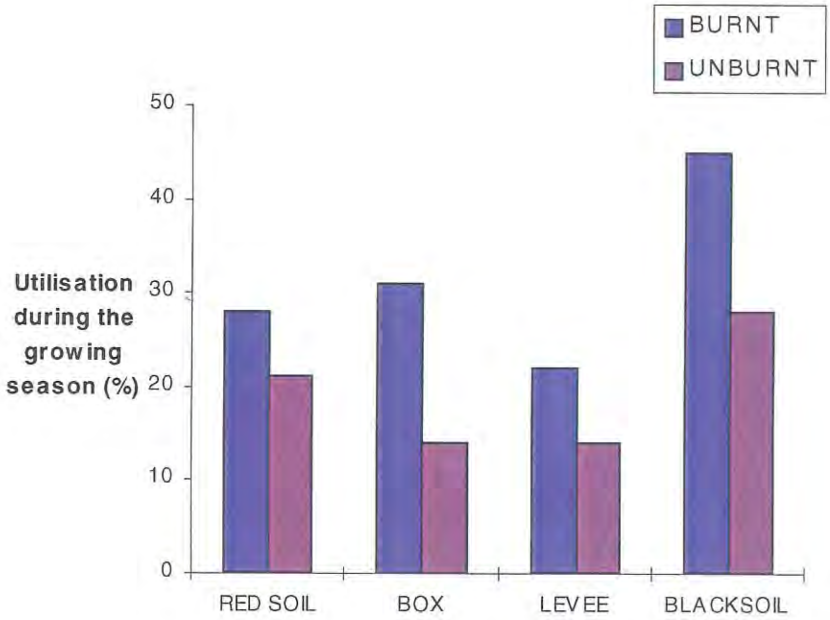



**Figure 11. The relative use of burnt and unburnt areas during the wet season for several different land types in a paddock.** Note that burnt areas attract greater utilisation, showing how fire could be used to reduce patch grazing.

### *3.3.3 Managing patch grazing*

Patch grazing is very common in grazing lands. Patches are small areas (typically tens of $m^2$ in area) that are either under-used or over-used by livestock. Patchiness itself is evident in ungrazed areas, due to local variations in soil type. Selective grazing interacts with this natural patchiness. Grazing animals tend to prefer the more productive patches or those patches with more leafy regrowth (often in Phase 1).

Some patchiness is desirable: it is a sign that animals have the opportunity to graze selectively, and a patchy pasture is likely to provide a higher quality diet than a uniform pasture. The problem with patch grazing occurs where the patches become persistent (Figure 12), and they are continually re-visited by cattle and maintained in Phase 1. These areas will decline in condition, causing loss of perennial grass cover and, on some soils, scalding of the soil surface.

**Figure 12. An example of persistent patch grazing**

Preventing development of persistent patches is achieved by:

- use of fire: animals prefer burnt areas (Figure 11). Pastures burnt every 1-4 years have far less patchiness than unburnt pastures. Fire brings the whole pasture back to Phase 1 so that animal preference for particular patches largely disappears. As long as grazing pressure during Phase 1 is well managed, such pastures maintain good land condition and show much more even use. In large paddocks, rotational burning of different areas in the paddock may be the best option to increase evenness of use.
- spelling paddocks: wet season spelling (every 3-4 years) will help over-used patches to recover.

### *3.3.4 Managing preference for plant species*

Grazing animals tend to show strong preference for certain plant species, and this preference is not readily controlled via grazing management (Figure 13). Periods of heavy grazing (as used in grazing systems developed overseas, eg, high intensity-low frequency grazing) certainly "force" animals to eat less preferred species, but not until they consume all they can of the preferred species. Such management just results in longer periods of rest being needed for recovery!

Time-control or cell grazing is sometimes promoted as a means of overcoming selective grazing. Results of research and practice do not support this claim.

Selective over-use of the better pasture plants is the primary cause of loss of land condition. Management to promote and conserve the better pasture plants is based around management of annual utilisation and use of wet season spelling.

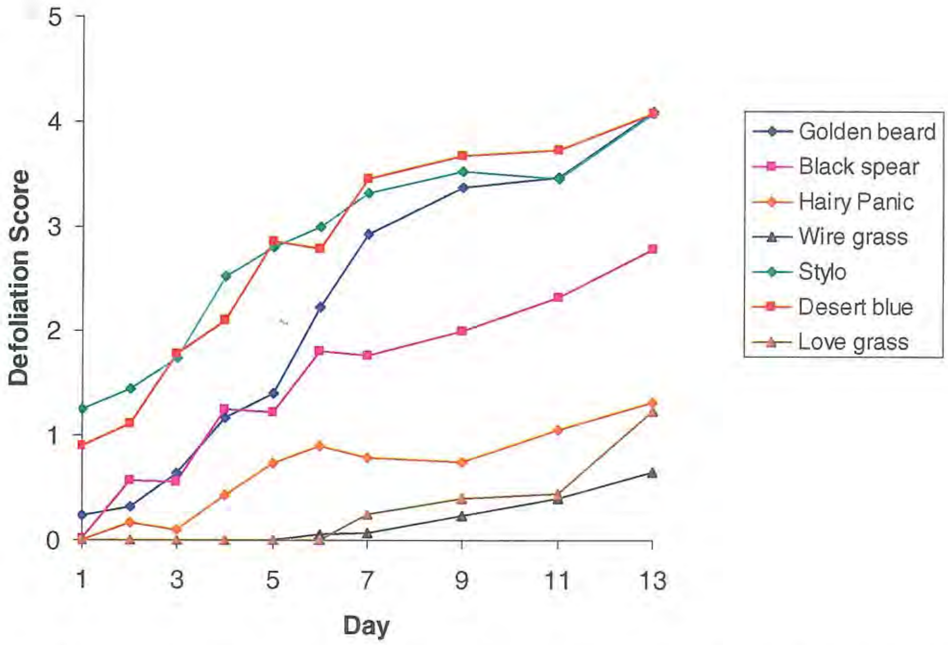



**Figure 13. The selective use of various plant species over 2 weeks in a paddock that was temporarily stocked at a high stock density to progressively deplete availability of preferred species.** The higher the defoliation score, the higher the cumulative grazing pressure on that species.

## 3.4 How can grazing management improve diet quality?

Diet quality is strongly related to 2 factors: forage quality and forage quantity. These 2 factors interact to determine diet quality. Forage quantity obviously varies throughout the year and from year to year.

Forage quality varies with:

- the growth phase of the pasture: forage quality is highest in Phase 1 and declines as pasture progresses along the growth curve (Figure 14). This is associated with increasing amounts of fibre and decreasing amounts of protein and sugars.
- the fertility of the soil: soils with higher levels of available N and P produce forage that is generally better quality than forage on low fertility country;
- the type of growing season: this has a major effect on average forage quality for the year. Years with moderate rainfall that is well distributed (prolonged growing season) have much higher quality forage then years with high rainfall over a short period (short growing season with dilution of nutrients).

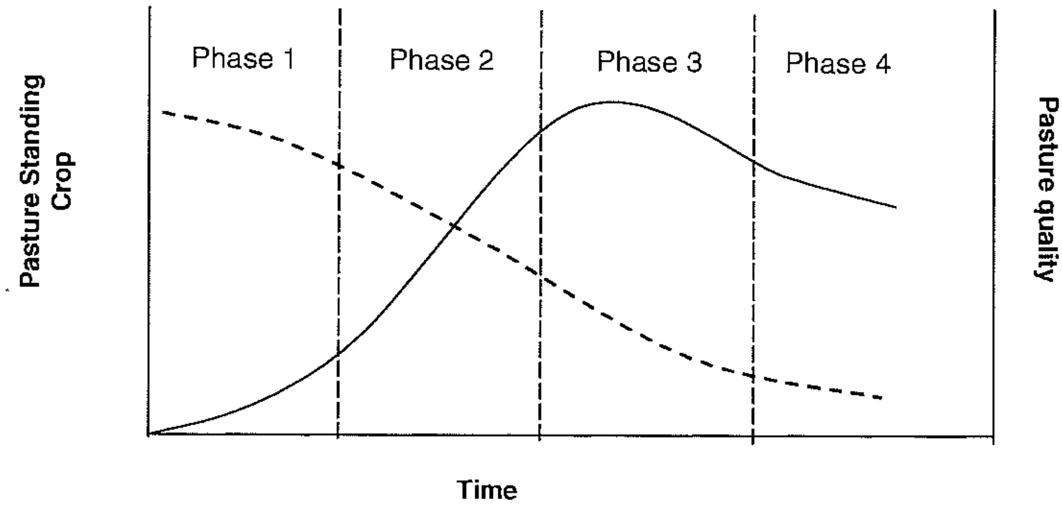



**Figure 14. The typical pattern in pasture yield (unbroken line) and pasture quality (broken line) during the 4 phases of pasture growth.**

Grazing management can affect diet quality in 2 ways:

- by influencing land condition, in particular the contribution of 3P grasses and
- most importantly, via utilisation level which determines how much animals compete with each other for the better quality pasture.

### *3.4.1 Effect of land condition on diet quality*

Generally the greater the contribution of leafy grasses to the pasture, instead of less leafy grasses or weeds, the more opportunity for animals to select a better quality diet. The effect of land condition on diet quality is not consistent, however.

Under certain conditions, the quality of the diet may be enhanced from grazing on land in condition 'B' rather than condition 'A'. This is caused by greater availability of native legumes and other forbs in some 'B' condition pastures. The effect will be most evident in years with short, sharp wet seasons that dilute the nutrient content of grasses. In most other years, the utilisation level associated with having condition B pastures will limit diet quality (see below).

### *3.4.2 Effect of utilisation on diet quality*

Utilisation level has a very strong effect on diet quality. For a particular paddock and year, annual production per head (eg, annual liveweight gain per head) is a good indicator of diet quality while stocking rate (eg, animals per ha or animals per 100 ha) is a good indicator of the relative utilisation level.

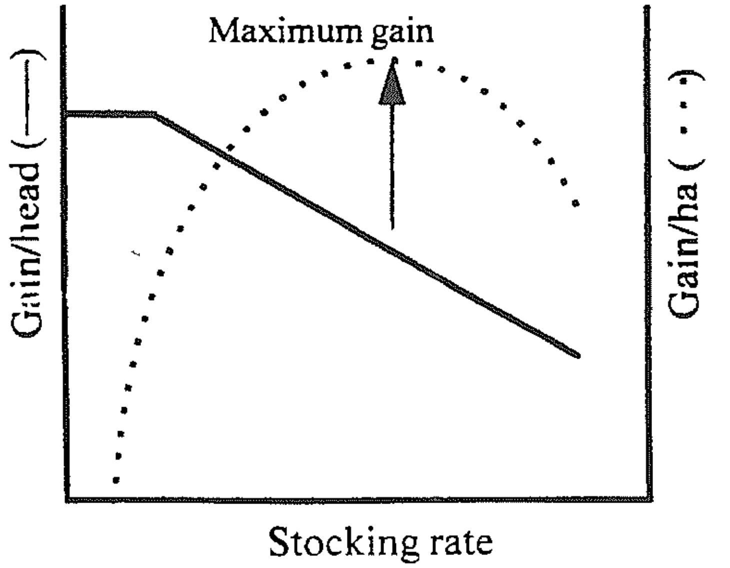



**Figure 15. General form of the relationship between stocking rate and production per head and per ha.**

Animal production per head is strongly affected by stocking rate: as stocking rate (ie utilisation) increases, animal performance per head declines (Figure 15). This decline is due to competition between animals for the most nutritious parts of the pasture. For example, at low stocking rates, animals have more opportunity to select out the green leaf from the preferred species. At higher stocking rates, the competition between animals intensifies and they are forced to eat less nutritious forage and performance declines. Lower stocking rates will therefore encourage higher production per head by permitting animals to be more selective.

### *3.4.3 Getting the balance between production per head, production per unit area, and land condition*

The balancing act in any grazing strategy is optimising animal production per unit area, while maintaining satisfactory animal performance per head plus good land condition. The stocking rate-animal production relationship (Figure 15) is a good way to visualise this balance.

As stocking rate increases, animal production per head declines at a particular rate or slope. This is a general relationship, and the slope of this line will actually vary in steepness with the type of year (in terms of rainfall amount and distribution), with type of animal, and with land type. In any case, animal production per unit area is low at low stocking rates, and increases to a maximum at an intermediate stocking rate. At stocking rates above this point of maximum production per unit area, the increase in animal number per unit area is not sufficient to compensate for the reduced production per head. To meet production targets such as liveweight targets for steers or reproductive rates for breeders, the optimum stocking rate will usually be below the point that maximises production per unit area. This is particularly the case for growing and finishing steers, where there are penalties from the market and in turn-over of animals if weight targets are not met. With breeders, the balance between production per head and production per unit area may be closer to the point of maximum production per unit area.

In all cases, the economic optimum is a stocking rate somewhat less than the stocking rate which maximises production per unit area, due to the impact of increasing variable costs and diminishing returns for each extra animal.

Where safe utilisation is consistently exceeded, land condition declines. This changes the stocking rate relationship (Figure 16): the decline in RUE and pasture growth means that equivalent stocking rates result in greater grazing pressure, more competition for the remaining desirable plants, and therefore more rapid decline in animal performance with increasing stocking rate.

Again, managing utilisation is the key to achieving goals for both land condition and diet quality. The perceived benefits to over-use of pasture (increased production per unit area) come at the cost of:

- reduced pasture growth, from declining land condition;
- reduced animal performance, from insufficient opportunity for selective grazing;

These effects compound each other, leading to erosion of safe carrying capacity, increased incidence of self-inflicted "droughts", and increased reliance on supplementary feed.

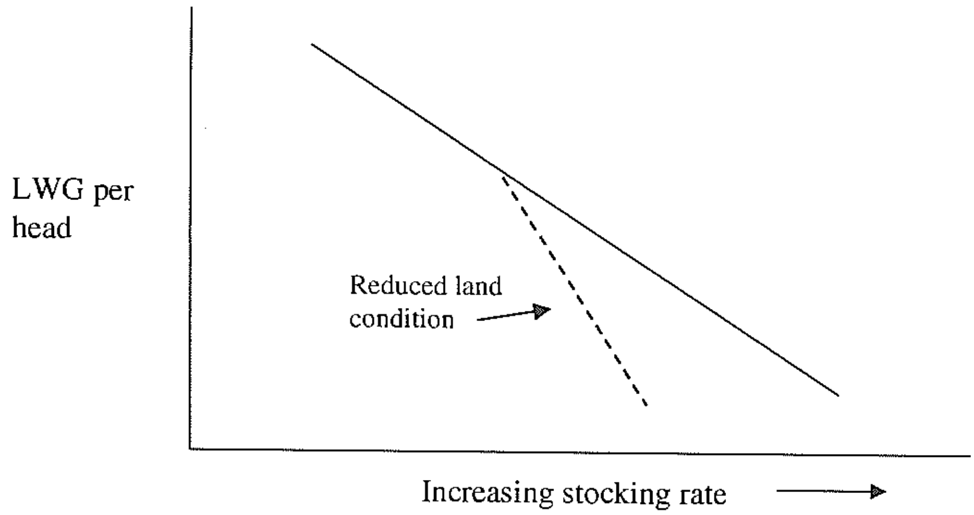



**Figure 16. The change in the stocking rate-liveweight gain (LWG) relationship when there is a change in land condition.**

### 3.5 Putting together a grazing strategy

The recommended steps for designing a grazing management strategy are:

1. Inventory and analyse current situation: calculate long-term carrying capacity.
2. Identify opportunities to improve rainfall use efficiency, optimise utilisation and improve conversion efficiency.
3. Select those options worthy of further evaluation, after considering likely impact on other parts of the operation and on landscape health.
4. Assess financial attractiveness of remaining options: select best-looking options.
5. Assess financial feasibility of remaining options: select those to implement.
6. Plan implementation, including monitoring and recording system;
7. Implement.

# 4. Using Fire

## 4.1 Why is fire important?

Lack of attention to fire management (either not enough, too much or inappropriately managed) is the cause of some common problems on grazing lands, such as:

- increased density of woody plants, both native and exotic;
- moribund pasture in under-utilised areas;
- decline in those desirable grasses that are favoured by fire;
- uneven use of paddocks;
- increased risk of wild fires; and
- increased risk of overgrazing

Fire strongly influenced the evolution of most grazing lands, and any grazing land management plan must consider the appropriate fire regime - the frequency, intensity and timing of fires that is consistent with production and sustainability goals. Using fire well is heavily dependent on implementing a grazing management strategy which is consistent with the desired fire regime.

Better fire management can improve all three gateways towards sustainable beef production:

- Rainfall use efficiency: improving land condition (eg, using fire to reduce density of woody plants or encourage the better pasture species) increases forage growth per mm of rainfall received, thereby improving carrying capacity and decreasing susceptibility to drought;
- Pasture utilisation: optimising level and evenness of pasture use (eg, using fire to reduce patch grazing and selective use of land types) increases the amount of forage that can be sustainably consumed by livestock and, thereby, carrying capacity;
- Conversion efficiency: improving diet quality (eg, using fire to improve amount and accessibility of green forage) improves the conversion of forage to beef, thereby helping to meet production targets.

The effects of fire are diverse, but its primary benefits come from control of the woody plant-grass balance and from increased evenness of grazing.

To understand how and when to use fire, we look at these questions:

- How can fire be used to improve land condition?
- How can fire improve evenness of use?
- How can fire be used to improve diet quality?
- How do you put together a fire management strategy?

There are no fixed recipes for fire management. Once-off or irregular fires can have many and varied impacts on grazing lands and animal production and much of the wide-ranging opinions about fire can be sourced to such experiences. The key issue is determining the most appropriate fire regime to meet your goals. The fire regime includes:

- the frequency of fire: eg, annual fires or fires every 3-5 years
- the timing of burning, eg, early in the dormant season or early growing season
- the intensity of fire: the rate at which heat is generated in a fire.

### *4.1.1 Ecological role of fire*

Fire has been a major factor in forming the structure of grazing lands, be they woodlands shrublands or grasslands, throughout the world and particularly in sub-tropical and tropical regions. In any region, the "natural" fire regime is largely determined by rainfall (amount, seasonality, reliability), nature of the vegetation, and ignition source (lightning, human). For example, the seasonally wet tropics (eg, Top-end of the Northern Territory) are naturally predisposed to frequent fire, as a result of the rapid biomass accumulation during the wet, followed by rapid curing during the dry season.

As the amount and/or reliability of rainfall decreases, fire is likely to occur less regularly, eg, natural fire frequencies vary from annually in the tropical woodlands of the top-end to once every 10-50 years in more arid environments like the mulga country.

A given piece of grazing land could likely support a plant community with a variety of structures and/or compositions. The fire regime often determines which type of plant community exists. While most plants species show some adaptation to fire (resprouting in woody plants; seed burial and protection of growing points in grasses), fire often controls the balance of woody plants and grasses, as grasses are less affected. In the absence of fire, most land types tend to increased woodiness; occasional fire retards this tendency and maintains a more open structure.

Some plants species are very sensitive to fire, eg, acacias, cypress pine and many species in heath and softwood scrub communities.

### *4.1.2 Historical incidence of fire*

Up until the arrival of aborigines into Australia about 50,000 years ago, lightning would have been the main source of ignition for fires. In tropical monsoon areas, intense lightning activity during the late dry and early wet would likely have initiated unchecked fires on an annual basis. Lightning would also have been the main source of fire in more arid zones, but the frequency and extent would have been far lower.

Aboriginal people used fire in a deliberate and skilled manner for numerous practical and cultural reasons. Aborigines usually started burning early in the dry season as the weather and vegetation dried. This practice created patchy burns, which maintained diversity and food sources. Early dry season fires broke up the continuous fuel loads so that extensive hot fires generally did not occur later in the year.

As aboriginal influence in land management diminished and European use (primarily for grazing) increased there were major changes in the fire regime within a district or region. These changes included:

- a change in timing of fire, from early-mid dry to late dry-early wet;
- a change in intensity of fire: in more remote or less intensively-managed areas, hot wild fires became more common;
- a change in frequency of fire: as grazing intensity increased, particularly in more closely-settled areas, there was less grass fuel in most years (as more grass was consumed by cattle) and therefore less opportunity for burning.

### *4.1.3 Fire management and biodiversity*

Native plants and animals are resilient to fire regimes, thus giving land managers a degree of flexibility in maintaining biodiversity. In general, biodiversity is maintained by a fire frequency of one per 3-5 years.

Burning regimes that promote patchiness in the vegetation provide a mix of habitats and are therefore associated with a more diverse collection of plants and animals. Frequent burning of grasslands at the same time of year will likely reduce floral diversity, promoting dominance by only a few species. In addition, frequent intense fires may also progressively reduce soil condition on some land types (via loss of litter input and loss of nutrients), affecting both below-ground and above-ground habitat value.

### *4.1.4 Fire behaviour*

Fire behaviour describes the intensity, extent, patchiness and rate of spread of a fire. The ability to quantify and predict fire behaviour is essential for the management of both planned burns and wildfires.

Fire behaviour is determined primarily by the interaction between weather factors and the amount and type of fuel, but is also affected by topography. Generally, fires in the northern half of Australia are fuelled by a ground layer of grass and litter and are therefore of relatively low intensity compared with the forest fires common in parts of southern Australia.

The amount and distribution of grassy fuel largely determine the frequency, timing and extent of wildfires, as well as opportunities for planned fires. Fuel loads vary with variability in rainfall and with grazing management. For uniform burns, fuel has to be continuous with more than 50% ground cover.

Fuel load is a key factor influencing fire behaviour because of its direct relationship with fire intensity. Curing refers to the greenness of the fuel; it indicates the moisture content of the fuel and thus its flammability and the rate of spread of the fire. Curing starts as soon as a grass has flowered, and accelerates after the end of the growing season.

Variations in factors such as air temperature, humidity and wind speed influence fire behaviour. In general, intensity and rate of spread of fires will increase with increasing temperature and wind and with decreasing humidity.

Wind speed is the most important weather influence on fire spread. As wind speed increases, flame angle also increases. This forces flames into unburnt material ahead of the fire front, resulting in more efficient preheating of the fuel and greater rates of spread.

Fires occurring in the early part of the dormant season are generally less intense than later fires. Potential fire intensity is greater in the late part of the dormant season because fuel is well cured, winds are stronger and atmospheric humidity is lower.

The vast majority of fires in grazing lands are surface fires, supported by the grassy understorey, as opposed to crown fires which burn in the canopies of trees and shrubs. Fires can burn as either head fires, burning with the wind, or back fires, burning against the wind. Head fires are generally of higher intensity, have a greater rate of spread and have a greater vertical distribution of heat compared to back fires. Head fires are more effective for suppressing woody plants and are less likely to damage perennial grasses.

Assessing fuel loads is aided by use of photostandards, as fuel load equates to pasture yield.

### 4.2 How can fire be used to improve land condition?

There are four main ways that fire can be used to improve land condition:

- controlling balance of woody plants and pasture;
- encouraging the desirable pasture species;
- helping to establish and manage sown pastures; and
- reducing risk of wild fires.

It is important to manage the risk factors for land condition that are inherent in the use of fire.

Note that many of the examples of using fire come from grazing lands that receive, on average, more than 600 mm of annual rainfall. This reflects the increased opportunities for burning compared to drier areas, as well as the lower risk of not receiving follow-up rainfall.

#### *4.2.1 Controlling balance of woody plants and pasture*

As density of woody plants increases, competition for moisture and nutrients usually leads to a progressive decline in pasture growth (note that there can be positive effects of low densities of woody plants on pasture growth and pasture quality in some environments). In many grazing lands, an increase in woody plant density has accompanied a historical reduction in frequency of fire, such that pasture growth and carrying capacities have declined. Reinstating regular fire can therefore lead to a reduction in woody plant density and increased RUE.

As most native woody plants tolerate fire well, the "control" of woody vegetation is generally through suppression of understorey growth (seedlings, saplings) rather than through plant mortality. Suppression of understorey regrowth and density is possible with regular fires and can occur over a range of fire intensities. In areas with average annual rainfall greater than 600 mm, a general rule is that burning frequency should be once every 5-6 years. Fuel loads of at least 2000kg DM/ha, fuel cover of at least 60%, as well as appropriate fire weather and fuel curing state are necessary for sufficient fire intensity. Timing of fire should be late dry season or very early in the growing season.

An example of the use of fire to suppress woody vegetation is currant bush (or berry bush) in eucalypt country of central and north Queensland. Regular burning removes the top-growth (Figure 1), and reduces canopy cover (Figure 2), thereby increasing pasture growth.

(a)

(b)

(c)

**Figure 1. Currant bush on box country prior to burning (a), after the fire (b), and reshooting strongly several weeks after the burn (c).**

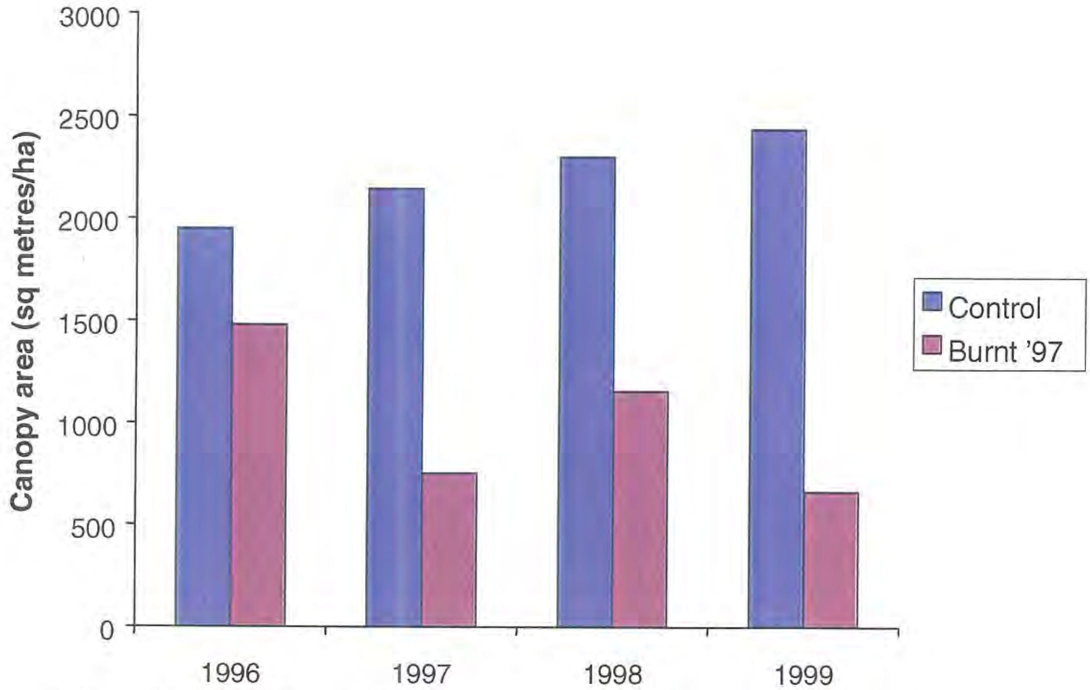


**Figure 2. The effect of fire on canopy cover of currant bush.**

When woody plants exceed 2-2.5m in height they are difficult to control. Very intense fires may increase mortality of shrubs and trees and such fires are required if areas of severe woody plant proliferation are to be returned to a more open state.

In more arid environments, management should be opportunistic, eg, burning after several years of good rainfall has accumulated sufficient fuel. In some situations, shrub densities have increased to levels where fire is either difficult to achieve or ineffective and integrated strategies involving the use of mechanical clearing and herbicides combined with fire are required.

### *4.2.2 Encouraging the desirable plant species*

Management of fire can improve pasture condition through encouraging the better pasture plants and discouraging both less desirable species and weeds.

Encouraging the better pasture plants is primarily dependent on grazing management but can be assisted by use of fire. Fire can assist because:

- Some undesirable pasture plants, such as the wire grasses, are often put at a competitive disadvantage when pasture is burnt, providing opportunities for the better species to increase in density.
- Some desirable pasture plants are encouraged by burning, eg, black speargrass.
- Some weeds are suppressed or reduced through use of fire, eg, rubbervine, parkinsonia. However some weeds, like Chinese apple and giant rat's tail grass, are little affected by fire.

- Use of fire avoids accumulation of excessive dead plant material, especially in areas of paddocks that are chronically under-utilised. Such accumulation of litter can reduce plant vigour and slow down nutrient cycling.

### *4.2.3 Helping to establish and manage sown pastures*

Fire has a role in both the establishment and maintenance of sown pastures. For example, native pasture is often burnt prior to oversowing of legumes such as stylos. Burning ensures that seed reaches the ground and reduces, at least temporarily, competition for light. Fire has had a key role in the conversion of Acacia shrublands (brigalow, gidgee) to pasture. Burning of fallen timber both cleans up the area of logs and provides an ash seedbed for sowing of grasses such as buffel.

Fire also has a role in influencing the balance of grass and stylo in environments where soils where stylo is prone to dominate the pasture. Infrequent but regular fire (every 5-8 years) may be required to restrict stylo dominance: stylo-dominant pastures create problems on some land types eg, lack of forage in the dormant season, potential loss of soil condition, soil acidity.

### *4.2.4 Reducing risk of wild fires*

Wild fire is a threat to land condition, as it may result in overgrazing of the Phase 1 regrowth particularly if there is low rainfall after the fire. Strategic burning can be used to reduce the quantity and continuity of grassy fuel, thereby reducing risk of wildfires. For example, the frequency and extent of wild late dry season fires in the top end of the Northern Territory is greatly reduced by increasing the amount of early dry season burning.

### *4.2.5 Managing the risk factors*

Use of fire creates risks for land condition, mainly because of the sudden and dramatic loss of pasture cover. Loss of nutrients to the atmosphere during the fire is also perceived to be a risk factor, but these losses are usually of minor significance.

Loss of pasture cover may lead to increased run-off and erosion while the fresh green pick (Phase 1 growth) will attract overuse. The risk to land condition through either increased erosion or overuse of desirable plants depends on:

- fire intensity and the amount of residual cover; residual cover can be encouraged by burning after the first significant rainfall. Figure 3 shows the residual cover for a fire that was lit 2 days after 58 mm of rain.
- the length of time before a critical cover level is restored and before the pasture growth rate exceeds the rate of consumption. This will depend, in turn, on land condition, likelihood of follow-up rain, soil moisture levels prior to burning, and grazing management.
- land condition, as run-off following burning is much less from areas in good condition compared to poor condition. This reflects the better condition of the soil, in terms of soil surface stability and infiltration rate, in good condition country (Table 1).

**Figure 3. The residual cover from a fire lit two days after 58mm of rain.**

**Table 1. The risk of excessive run-off after burning is affected by land condition.** In this example, good condition light ironbark country was burnt in spring and its cover and run-off levels then compared to an adjacent area in fair condition that was unburnt.

| **Condition of light ironbark country** | **Ground-cover (%) at end of November (one month after good condition area was burnt)** | **Runoff (% of rainfall) during November (ie in month following burning of good condition area)** |
|---|---|---|
| Fair condition paddock (not burnt) | 50 | 18 |
| Good condition paddock (burnt October) | 40 | 3 |

The cautious approach is to burn only after significant rainfall in those years with relatively high probability of follow-up rain (based on SOI etc.), and to have the capacity to reduce grazing pressure until cover is restored. Also, only limited proportions of the whole property should be burnt in any one year.

When plant material is burnt, some elements (P, K, Ca) largely remain in the ash, while others (C, N) are lost as gasses to the atmosphere (Figure 4). The potential loss of N is of major interest as productivity of grazing land is often limited by availability of N.

Although up to 90% of the N present in the plant material at the time of burning is lost to the atmosphere during the fire, the actual losses are small. This is because the plant material at the end of the dormant season has little N remaining in it (most is relocated to the roots). Also, the loss is small (a few kg of N/ha) when compared with the total amount of N in the soil (several thousand kg per ha). Input of N in rainfall often compensates for any loss in fire. In most cases, therefore, direct loss of nutrients due to burning is an insignificant risk. A more important risk is indirect loss of nutrients due to reduction in ground cover and increased erosion, but this risk can be managed (see above).

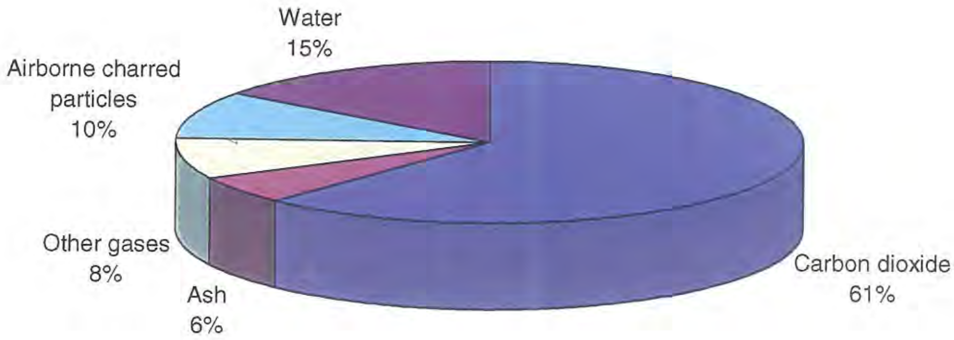



**Figure 4. The fate of pasture fuel when it is burnt**

It is also important to note that fire has little impact below the soil surface (soil is insulated against large increases in temperature), so that biological activity in the soil is not directly affected.

Perennial grasses are well adapted to fire, but they may be damaged by fire that occurs during periods of active growth. Burning during the growing season is therefore not recommended in most situations.

## 4.3 How can fire be used to improve evenness of pasture use?

Evenness of use of pastures is improved by fire through reduction of selective grazing. There are some risks inherent in this approach, which need to be managed.

### *4.3.1 Using fire to help manage selective grazing*

Cattle tend to graze selectively, preferring certain land types and plant species. Uneven forage use can limit carrying capacity and lead to a decline in land condition. Selective grazing habits are often reinforced and amplified by patch grazing, where cattle tend to return to previously grazed patches, ignoring other areas of more mature pasture (Figure 5). We discussed some of the options for managing selective grazing in the grazing management section. Use of fire is one of these options.

The influence of fire on grazing pressure can be used in 2 ways. Firstly, by burning all or most of a paddock, the pasture is brought back to Phase 1 so that animal preference for particular patches largely disappears. As long as grazing pressure during Phase 1 is well managed, such pastures maintain good land condition and show much more even use. Burning can be repeated as required, usually once every 3-5 years.


**Figure 5. Examples of persistent patch grazing.**

Alternatively, parts of paddocks that are being under-grazed can be burnt, attracting cattle away from over-used areas (Figure 6). Areas of paddocks can then be burnt on a rotational basis as a means of evening out grazing pressure. The success of this approach depends on burning sufficient area so as to avoid excessive concentration of stock on the freshly burnt areas. Such rotational burning is suited to very large paddocks, helping to break up the pattern of selective use. Where paddocks are a mix of hills and flats, burning the hills encourages cattle to work that country, effectively giving the flats a spell from grazing

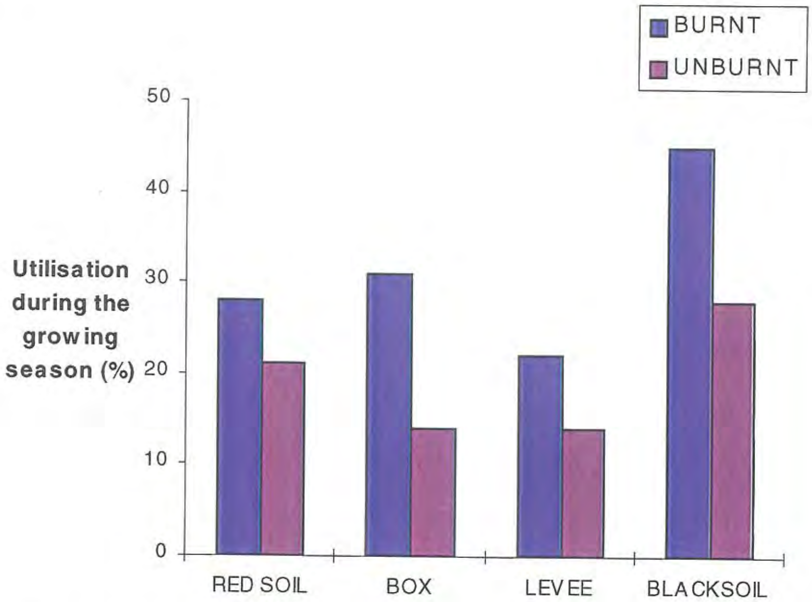



**Figure 6. The relative use of burnt and unburnt areas during the wet season for several different land types in a paddock.** Note that burnt areas attract greater utilisation, showing how fire could be used to reduce patch grazing.

#### *4.3.2 Managing the risk factors*

Burning only small areas within a paddock can lead to excessive concentration of grazing pressure in those areas. Such areas may not advance beyond Phase 1 growth stage, so are susceptible to damage from overuse. Paddock burning should therefore include significant areas of a paddock, eg at least a third to a half of the area.

### 4.4 How can fire be used to improve diet quality?

Fire can improve diet quality, at least temporarily. Again, there are risk factors which need to be managed.

#### *4.4.1 Using fire to improve forage quality*

Diet quality is strongly related to two factors: forage quality and forage quantity. These two factors interact to determine diet quality.

Burning of pasture late in the dormant season or early in the growing season can increase subsequent cattle production although there are contradictory reports on the size and persistence of the benefit. Improved cattle liveweight gain (LWG) is associated with increased nutrient content of post-fire regrowth, increased proportion of green leaf in the pasture and in the diet, and greater accessibility of green material (Figure 7). The improved LWG tends to occur mainly in the first half of the growing season. Unless this benefit is captured by sale of animals towards the end of the growing season, the net benefit to annual LWG may be relatively small, ie, the benefit to liveweight may not carry over into the following growing season.

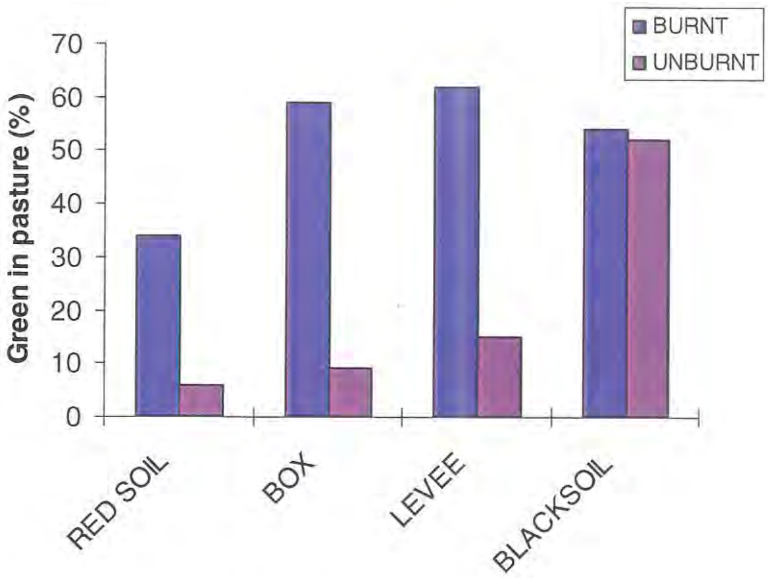



**Figure 7. The effect of burning at the start of the growing season on the proportion of green in the pasture at the end of the growing season, for four different land types.**

Late wet/early dry season burning is sometimes practiced with the intention of stimulating pasture regrowth and thereby extending the growing season, but trials have not recorded benefits to LWG from this practice. Wet season burning is generally discouraged as there is a risk of loss of pasture condition.

### *4.4.2 Managing the risk factors*

The major risk for diet quality is insufficient forage, due to poor pasture growth post-burning. This risk can be reduced by burning only after significant rainfall in those years with relatively high probability of follow-up rain (based on SOI etc.), and by having the capacity to reduce grazing pressure until pasture gets beyond Phase 1 growth. Risks are reduced in a similar way as with the risk of prolonged low groundcover and the risk of overgrazing. Clearly, flexibility in grazing management is a key factor in managing risks associated with the use of fire.

Other possible risks of reduced animal performance from use of fire include:

- animals 'chasing green pick': anecdotal reports abound of cattle chasing new green forage, ignoring any residual standover forage, and "losing condition" as a consequence. The perceived loss of condition is likely to be mainly due to a change in gut contents, rather than significant loss of body tissue.
- increase palatability and potency of toxic plants: an example is heart-leaf poison bush (*Gastrolobium grandiflorum*), new growth of which is more toxic and attractive to cattle. Other potential examples include grasstrees (*Xanothorrhoea* spp.), indigo (for horses) and lantana. In these situations, stock may need to be excluded from the paddock until pasture has regrown and the risk of animals eating toxic plants is reduced.

## 4.5 How do you put together a strategy for use of fire?

Planning a fire strategy must be done in concert with planning other parts of the operation, especially grazing management. Achieving the desired frequency, timing and intensity of fire for a particular paddock or group of paddocks, as well as minimising the risks to land condition and forage supply, will depend largely on how well the grazing strategy is developed.

For regions with > 600 mm average annual rainfall, a general guideline is to burn each paddock every 3 to 5 years at the end of the dry season or immediately after the first rains. Minimum fuel load should be 1500-2000 kg of dry matter per ha. This is usually sufficient to suppress woody species, to manage patch grazing, and to encourage the desirable pasture plants. In situations where woody species are dense, or undesirable pasture plants dominate, more frequent or more intense fires may be required to initiate desired changes. Reduce risk by not burning more than 40% of the whole property in any one year. In smaller paddocks, limit localised overgrazing by burning most or all of any one paddock.

In drier regions, fire should be used opportunistically for a specific purpose. Obviously, use of fire should coincide with a run of reasonable years.

A desirable fire regime for a particular paddock or group of paddocks need not (and should not) be a non-changing "recipe" or prescription. However, the attributes of the appropriate fire regime must be specified in general terms.

Often, the fire regime will have several objectives, eg. to suppress woody understorey and to improve pasture condition. The fire regime must always be responsive to the condition of the land and to patterns in climate (eg. runs of above-average or below-average years).

### *4.5.1 Analysis and planning*

The key steps are:

1. For each paddock analyse:
    - what the current fire regime is;
    - opportunities for the better use of fire to improve land condition, evenness of use, and diet quality; and
    - what fire regime is required to achieve this, specifying the required frequency, intensity and timing of fire.

2. Design a strategy for achieving, over time, the desired fire regime for each paddock. Factors to consider:
    - what area of the property or numbers of paddocks should be burned each year, eg, aim might be to burn at least 10% of property each year on a rotational basis ;
    - the priority of paddocks for burning, based on their pasture composition, weed types and density, balance of woody plants and grass, selective grazing and patchiness;
    - ways of managing risk factors such as poor pasture regrowth by seasonal forecasting and flexibility in grazing management (including having sufficient paddocks to provide flexibility); and
    - effective ways of monitoring land condition and evenness of use.

3. Ensure the grazing strategy is consistent with the fire strategy.

The critical role for grazing management was described earlier. Grazing management is the key to creating opportunities for fire that are consistent with the desired fire regime (through management of fuel load). Otherwise, opportunities will be dictated purely by seasonal conditions and, even when favourable conditions occur, they are likely to be subjugated by other needs (such as short-term forage demand).

Grazing management is also the key to facilitating post-fire pasture recovery. The capacity to spell or partially destock pasture in response to changing conditions is a prerequisite for successful fire management. Creating opportunities for fire and facilitating post-fire recovery are both greatly enhanced by:

- sustainable utilisation levels: utilisation levels consistent with good land condition will usually generate accumulation of fuel at intervals suitable for most fire regimes;
- flexible stocking rates: matching animal numbers to runs of years with above-average and below-average rainfall will help generate fuel accumulation in most years;
- multi-paddock grazing systems: any system which encourages subdivision of paddocks will automatically provide the opportunity for more flexible management. Even splitting one large paddock into two provides a large boost to the options available, eg. short-term spelling for fuel accumulation or pasture recovery. As the number of paddocks increases, one or more can be spelled with decreasing impact on herd management and animal performance, and with less risk of non-spelled areas being overgrazed.
- using seasonal forecasts to manage both fuel build-up, timing of the burn and pasture recovery.

***4.5.2 Operational planning***

Each region will have regulatory requirements for the safe use of fire, including a process for applying for a permit to burn. This requires attention to basic issues such as fire breaks and availability of both trained fire-fighters and appropriate fire-fighting equipment.

Factors to attend to include:

- property map for planning and recording of fire history;
- involvement of the local Bushfire Brigade or fire service;
- location and width of fire breaks in relation to method of lighting, preferred wind direction and strength, and fuel load;
- number of trained personnel and safety gear required on the day of burn; and
- necessary conditions on the day for an effective and manageable fire, eg, wind strength and direction, cloudiness, humidity.

# 5. USING SOWN PASTURES

## 5.1 Why are sown pastures important?

Most grazing lands are dominated by native and naturalised pasture species. Sown pastures are used for 2 main reasons:

- as the main source of pasture for grazing lands where native pasture species are not abundant, eg, for land cleared of brigalow or gidgee, or in areas cleared of rainforest or dense coastal eucalypt forests.
- as replacement for, or as an addition to, native pastures with the aims of increasing liveweight gains (thereby reducing age-of-turnoff) and increasing carrying capacity. Traditionally, native pastures have been viewed as being inferior in quality and quantity for animal production. An early approach was to completely replace native pasture with sown grasses and legumes. In recent times, however, there has been more emphasis on:
  - better grazing management of native pastures, and
  - adding legumes into native pasture.

Other reasons for using sown pastures include:

- To concentrate stock onto smaller areas, giving better stock control and reducing cattle handling costs.
- To reduce grazing pressure on native pastures, especially at critical times like early in the growing season.
- To provide special purpose pastures eg, for first-calf heifers, for hospital paddocks, for recently-weaned stock, for crop-pasture rotations (to help restore soil condition).
- To restore degraded lands: sown pastures have been widely used to reclaim bare areas – these are sometimes small areas (roadsides, mining areas) but there have also been large programs, like the Ord River Regeneration Project.

Sown pastures have more commonly been referred to as 'improved' pastures. However, we are now more aware that using pasture species introduced from overseas does not always guarantee a persistent or financially attractive outcome compared to use of native pastures. For example, introduced grasses are not always inherently better than native species. As we will see, any advantage is dependent on the level of soil fertility. So we will use the term "sown pastures" to refer to the intentional use of introduced species; whether their use results in actual improvement needs to be assessed on a case by case basis.

Sown pastures can enhance 2 of the gateways towards more sustainable beef production:

- Rainfall use efficiency: use of sown pastures (eg, legume-based pastures or newly-sown grass pastures) can increase RUE, thereby improving carrying capacity.
- Conversion efficiency: improving diet quality (eg, through use of legumes) improves conversion of forage to beef, thereby helping to meet production targets.

Sown pastures can help also take some pressure off native pastures at critical times, thereby leading to more sustainable use of the whole property. Sown pastures should be considered as part of the total grazing strategy.

In making decisions about whether to use sown pastures you need to ask the following questions:

- Why do you need a sown pasture? What are the benefits and are these economic?
- What kind of pasture will fill this role?
- Are there suitable areas on the property for sown pastures?
- How will you go about establishing pasture on your property?
- How will you manage these pastures once established?

## 5.2 How can use of sown pastures improve land condition?

Use of sown pastures can improve land condition by:

- Exploiting situations of higher soil fertility, due to either natural causes (eg, build-up of N under brigalow and gidgee forests, or under leucaena pasture) or to human intervention (eg, through increased mineralisation following cultivation, or through use of fertiliser);
- Direct improvement of soil fertility, eg, pasture legumes increasing soil N;
- Providing greater tolerance to grazing.

### *5.2.1 Exploiting situations of higher soil fertility*

The soils under brigalow and gidgee forests have accumulated relatively high levels of soil N, due to fixation of N by the roots of these leguminous trees. Once cleared, sown grasses (buffel, rhodes, green panic) are commonly used to exploit this fertility. In the absence of sown pasture, forage production would be limited because:

- There is often only a very low density and variety of native grasses in these woodlands, and
- Native grasses cannot respond as well to the levels of soil N available: the native species reach their maximum productivity at lower levels of soil available N.

The effects of sown pastures on carrying capacity are most marked in these situations. For example, brigalow lands could support about 1 steer/20 ha in their original state and 1 steer/4-5 ha after clearing but with no sowing of other grasses. In contrast, recently cleared brigalow country near Theodore sown to buffel grass and green panic pastures and grazed by Hereford steers produced annual liveweight gains of approximately 180 kg/head at a stocking rate of 1 steer/0.7 ha.

The productivity of pastures on cleared brigalow and gidgee country remains high for many years, as the grasses make use of the high amounts of available soil N. However, there is a gradual rundown in the level of *available soil N*, and productivity also gradually declines. It may take 20-50 years before obvious signs of reduced productivity are noticed, depending on the initial level of fertility. These signs include a decline in animal production (expressed as a higher age of turn-off and/or reduced carrying capacity), as well as a decline in the presence and vigour of the sown species. Native grasses, better adapted to the lower levels of available soil N, start to colonise the pasture. This tie-up of N is a natural process (see below).

The over-riding importance of available soil N to the productivity of sown grasses is also demonstrated by experience in the less fertile eucalypt woodlands. There was a common belief that introduced grasses were inherently superior to native species, and areas of eucalypt woodland were therefore cleared and sown to grasses such as buffel, rhodes grass and green panic. Such pastures were more productive than native pastures at first, but this time the run-down in productivity occurred quickly (noticeable signs by 3-5 years after sowing) and the pastures were gradually re-colonised by native species. Here, the newly sown pasture is exploiting a boost (run-up phase) in available soil N that is a result of the cultivation used to establish the pasture. Cultivating the soil improves conditions for mineralisation, causing this run-up in available soil N. However, there is then a decline in available soil N (run-down phase) to pre-cultivation levels. This will take only 3-8 years on most eucalypt country, depending on the inherent fertility of the soil. Figure 1 illustrates this run-down for green panic pastures in the Burnett region.


**Figure 1. Live weight gain in relation to pasture age for steers grazing green panic pastures at Gayndah in winter and spring.**

The run-down in available soil N represents the progressive conversion of available N to organic forms in the soil (Fig 2). The release of N from the large reserve of organic N is limited by the rate of mineralisation. N tends to get tied up in low-quality litter and in roots, which only mineralise slowly due to the high ration of C to N. This limits the activity of the soil micro-organisms responsible for breakdown and mineralisation of organic material. Also, the micro-organisms are forced to use N from the pool of available soil N to help break down the poor quality organic material, thus, further limiting the amount of N available for plants. Hence, there tends to be a decline in the amount of N made available for plant uptake each year, until the rates of mineralisation return to the levels that occurred prior to sowing the pasture. There is no net loss of total soil nitrogen associated with rundown; rather it is a result of the N cycle returning to a more "normal" level of operation.

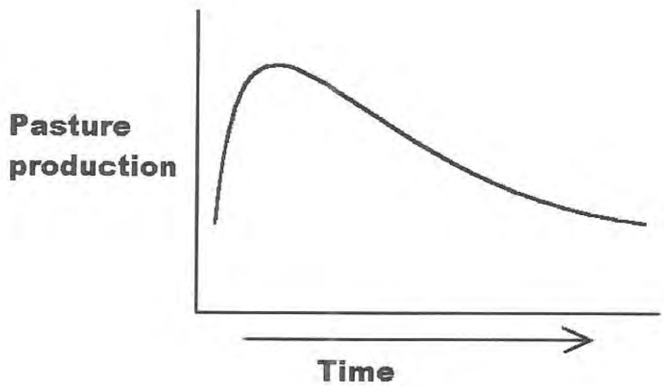



**Figure 2. Run up and run-down of pasture productivity over time after an initial soil disturbance eg cultivation.**

Productivity of sown grass pastures is therefore dependent on the level of available soil N (many introduced grass species have relatively high requirements for P which will also limit their usefulness). For example, Figure 3 shows that native and introduced grasses show little difference in productivity when compared at the same level of available soil N. In this case, native grasses (black speargrass and forest bluegrass) were included in the comparison. Their productivity was no less or no more, on average, than any of the other grasses. This work illustrated that, so long as the grass is palatable and productive, it is not the grass that influences production so much as the available soil N.

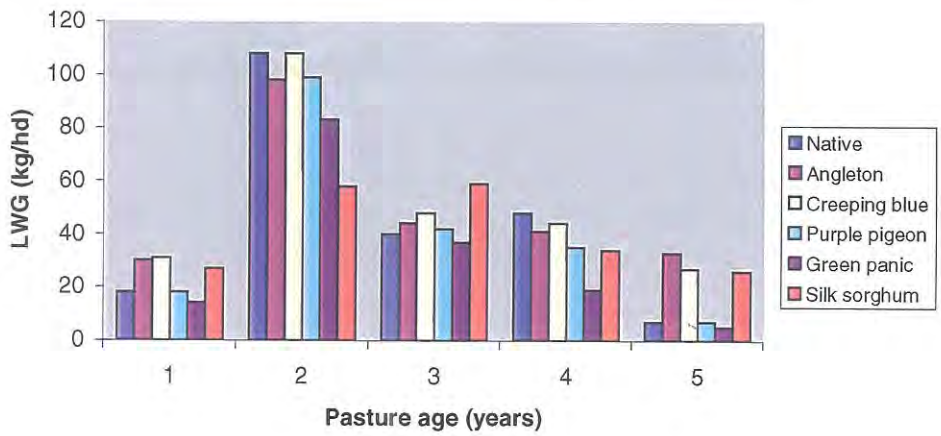



**Figure 3. Liveweight gains from different grass pastures compared on equal terms**

On eucalypt country, the benefits to land condition of ploughing out native pasture to sow introduced grasses must be questioned. The likely increases in carrying capacity will vary widely depending on the productivity of the native pasture, the type of pasture improvement, and the productivity and persistence of the sown pasture. Benefits will be short-term at best, and the financial implications should be assessed carefully.

### *5.2.2 Direct improvement of soil fertility*

Direct improvement of soil fertility is mainly associated with use of pasture legumes, associated with the fixation of N by rhizobia in the soil. Grasses can form associations with mycorrhiza or other micro-organisms which may benefit grass growth, but the impact on soil fertility is minimal.

Legumes form a symbiotic relationship with bacteria (*Rhizobium* spp.) in the soil. These bacteria live in small gall-like nodules on the plant roots and "fix nitrogen" by converting nitrogen from the atmosphere to organic nitrogen compounds. The bacteria obtain their energy requirements from the legume and in return provide the legume with nitrogen. This nitrogen is made available for use by other plants through leaf litter and through break down of the legume plant material and the root nodules after the plants die.

The amount of nitrogen fixed is related directly to the amount of legume growth in the pasture: the greater the legume growth, the higher the amount of N that is fixed. For example, pastures based on legumes like lotononis, siratro or verano, may contribute 20-50 kg N/ha/year, while pastures based on leucaena may contribute up to 180 kg N/ha/year.

Legumes vary in their sensitivity to supply of other nutrients, especially P. Legumes like leucaena and siratro need relatively fertile soils (>10-20 ppm of P) to be productive, while the stylos are unusual in their ability to grow on low P soils (<5 ppm).

Because legumes are not dependent on nitrogen from the soil, they have a number of advantages as pasture plants. Since nitrogen is the limiting plant nutrient for most grazing lands, well-adapted legumes can produce large increases in pasture growth (ie increased RUE) provided other factors are not limiting (such as other nutrients). This increase comes both from the production by the legumes themselves, and superior growth of associated grasses as soil nitrogen levels are increased.

The value of legumes for increasing the quantity of pasture will depend on whether water or nitrogen is most limiting for growth. In arid areas, water will be the major limiting factor for pasture production and including a legume would have little impact on pasture growth. However in wetter areas (>600mm average annual rainfall), nitrogen will often limit pasture growth and use of legumes will therefore boost pasture growth in most years. Carrying capacity will therefore be increased, although the benefit will vary depending on region, productivity of the native pasture and the type of sown pasture.

### *5.2.3 Providing greater tolerance to grazing*

Some introduced grasses appear to tolerate grazing pressure better than either native grasses or other introduced species. These grasses are commonly low-growing species with stems that trail along the ground and root at the nodes to form a dense ground cover.

The spread of species like indian couch, blue couch and sabi grass is often associated with overgrazing of the native pasture, creating bare ground which is then gradually colonised by these types of grasses. Whether such pastures can be considered to be "improved", albeit unintentionally, is an interesting question. In some cases, the land has suffered loss of soil condition during the period of over-grazing that promoted these grasses. Hence, potential production has probably dropped. Also, the productivity of these grasses is determined by soil available N, just like it was for the native species they replaced. On the positive side, these grasses may provide more soil protection than native species under poor grazing management. If so, they do provide some benefit, although it may come at the cost of encouraging poor grazing management. Certainly, there are cases where the land manager believes these grasses are immune to grazing pressure; ironically, this approach to grazing management can result in levels of pasture cover that rarely exceed the critical levels, even in good seasons!

There may be a case for using these grasses to protect soil in areas of paddocks that are difficult to manage, eg, areas of better soil that are selectively overgrazed.

## 5.3 How can sown pastures improve diet quality?

The pattern of animal production during the year mirrors the pattern in nutrient content of pasture; typically, animals gain weight quickly during the first part of the growing season (pasture in Phases 1 and 2), more slowly during the second half of the growing season (Phases 2 and 3), and either lose weight or just maintain liveweight over the dormant season (Phase 4). Sown pastures can improve diet quality if they:

- Provide higher levels of protein and energy during at least 1 of the growth phases.
- Extend the growing season, ie, extending the time that pasture is in growth Phases 2 or 3;

### *5.3.1 Providing higher levels of protein and energy*

Due to their superior nitrogen supply, legumes are generally higher in protein, digestibility and minerals than grasses. Young growth of legumes and grasses (ie, Phase 1 growth) is usually of similar quality but the rate of decline in quality as the pasture grows and matures is much slower for legumes. Cattle grow faster on legume-based pastures for most of the year but the main advantages occur during the later part of the growing season and during the dormant season. Figure 4 illustrates the benefit of Seca stylo oversown into native pasture. The greatest benefit to legume inclusion accrues in the autumn/winter period.

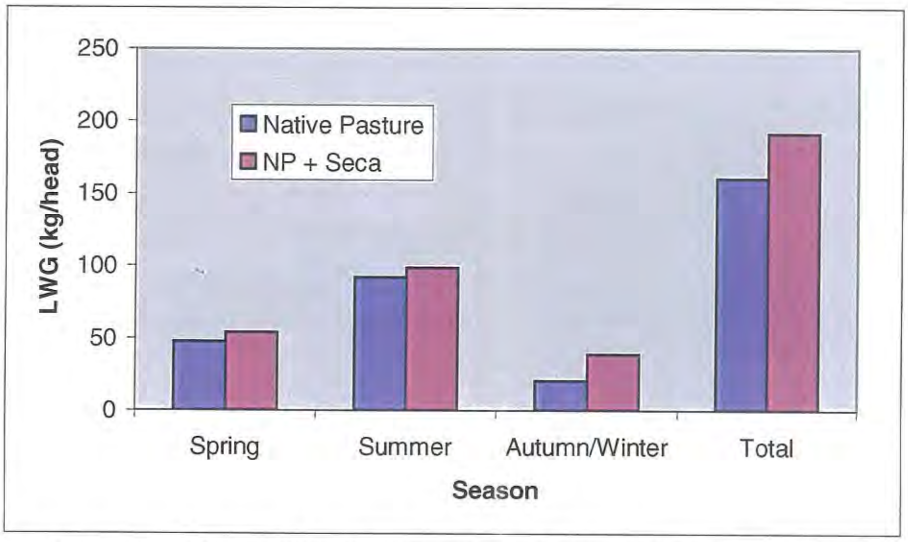



**Figure 4. Seasonal liveweight changes of cattle on native pastures and native pastures oversown with Seca stylo at Galloway Plains.**

Higher weight gains mean that cattle reach market weights earlier, allowing for higher rates of stock turnover. The combination of higher carrying capacity (due to improved RUE) and improved diet quality from grass-legume pastures gives large benefits to total production per ha.

The importance of legumes in maintaining the productivity of sown pastures was well illustrated at Brian Pastures near Gayndah. A range of legume types (leucaena, Seca stylo and annual legumes) was compared with grass only pasture and grass fertilised with N (Figure 5). Cattle production was greatest from the leucaena-based pasture; leucaena is a shrub legume and, hence, has greater productivity than its lower growing counterparts. Production was least from the unfertilised grass-only pasture that would have immediately started to rundown after sowing.

Since leucaena is both high yielding and high quality, leucaena pastures can support higher levels of animal production than other legume-based pastures. These pastures can be used for grazing throughout the year or to supplement grass-only pastures during the dry or cool season.

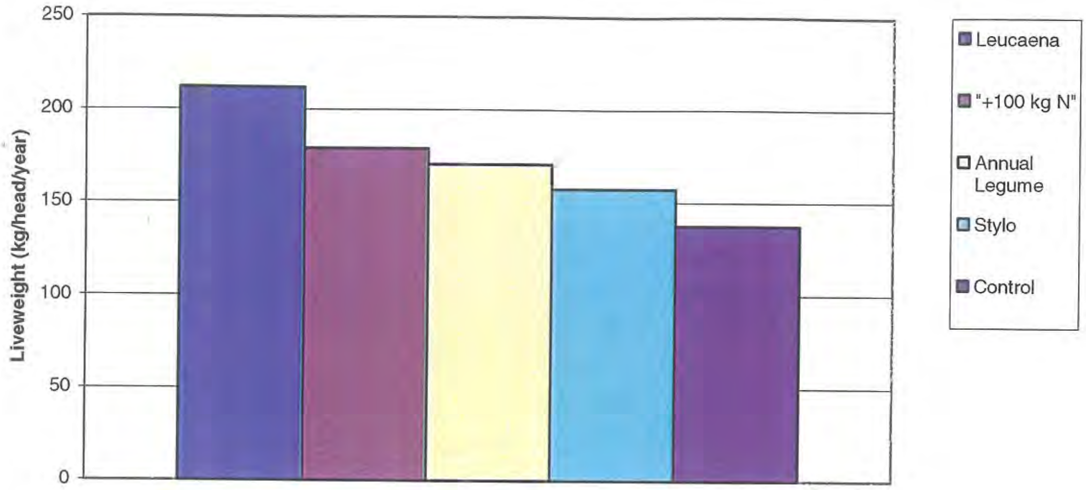



**Figure 5. Average annual liveweight gain (kg/hd) of steers from 5 pasture types ; data from 7 years (1989 - 1996).**

### *5.3.2 Importance of soil fertility.*

As discussed earlier, sown grass pastures provide higher levels of protein and energy if they are exploiting higher levels of available soil N. The establishment and persistence of many introduced grasses is also dependent on having relatively high levels of soil P.

The growth of many legumes is also dependent on an adequate supply of soil P. The stylos are unusual in their ability to grow well on low P soils. However, the phosphorus concentration in these stylo plants may be deficient for animal growth, and this will reduce the response to the additional protein provided by the legume. This is readily corrected by providing phosphorus directly to the animals as a feed supplement throughout the year, and particularly during the growing season. Feeding P to steers grazing stylo-based pastures on very low P soils (<5 ppm) can more than double their rate of liveweight gain (Figure 6).

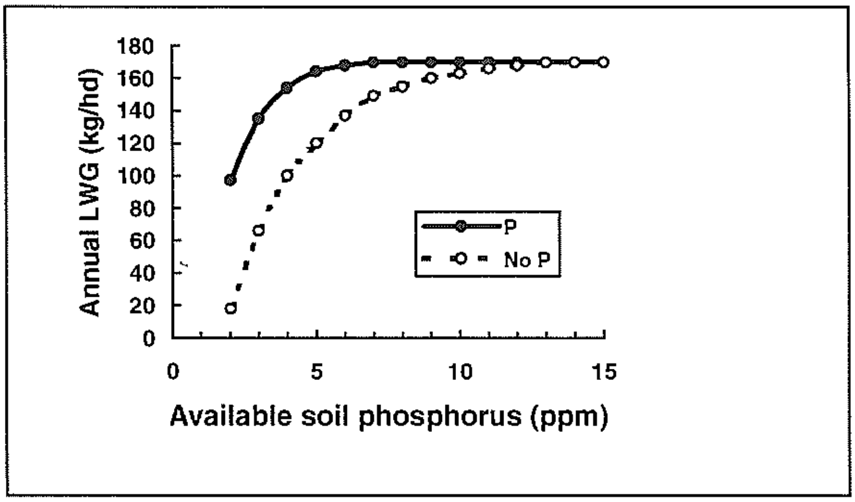



**Figure 6. Relation between annual liveweight gain and extractable soil phosphorus for phosphorus supplemented and non-supplemented cattle grazing legume-based pastures in northern Australia.**

### *5.3.3 Extending the growing season of the pasture.*

Green leaf is higher quality than other plant components. Therefore, any increase in the proportion of green leaf will increase herbage quality – this could come from more rapid response to rain, staying green longer at the end of the wet season, or having an inherently higher leaf:stem ratio.

Legumes can continue to grow at the end of the growing season, given soil moisture is available; grasses, on the other hand, usually cease growth as most or all the available soil N has been taken up by that time.

Some introduced grasses are reputed to start growth earlier, and continue growth longer, compared to native species. In the sub-tropics, this may occur if the sown species are able to grow at lower temperatures than the native grasses, but would only be an advantage if soil moisture was not limiting. Buffel grass is reputed to extend the growing season because of its deeper root system allowing use of soil moisture that may not be available to native grasses. The benefit of this to animal performance in terms of weight gain, compared to a well-managed native pasture (with similar available soil N) is uncertain. Good condition native pastures are usually a mix of species (grasses and forbs) with varying growth curves, so these pastures should also have advantages for extending the growing season.

As long as grass species are palatable, perennial and have similar leaf:stem ratios, there is probably little to be gained in arguing the benefit of one grass species over another. This is well illustrated by results from a trial near Gayndah that compared a variety of grasses that were all sown under the same conditions: no consistent ranking of one grass over another was measured over the 5 years (Figure 3). Again, it's the available soil N that drives grass production and quality, not minor differences between grass species.

## 5.4 Managing risk factors

The benefits to land condition from using sown pastures can be reduced or compromised by:

- Poor establishment of pasture
- Poor persistence of pasture
- Legume dominance, which may lead to problems with soil erosion and soil acidification
- Localised effects on diversity and landscape health
- Weediness and off-site effects on landscape health

### *5.4.1 Poor establishment.*

Reliability of establishment is a key factor determining the value of sown pastures. The risk of poor establishment is least in regions with more reliable rainfall; rainfall reliability is higher on the coast and decreases with distance away from the coast; rainfall reliability also declines from north to south.

Sowing methods for water, nutrients and light reduce establishment and these can influence both poor germination conditions and competition from other plants. Methods of sowing range from low-cost but high-risk methods (eg, aerial sowing) to more expensive methods with higher chances of success (eg, strip or full cultivation).

### *5.4.2 Poor persistence.*

Poor persistence is commonly associated with the legume component of pastures, especially in drier sub-tropical areas. Finding hardy legumes that can tolerate a range of soil types, survive through cold winters, and tolerate a range of grazing pressures has been difficult. Twining legumes like siratro were widely planted in the 1970's but often did not persist under conditions of low fertiliser input and/or periods of heavy grazing. Persistence has been less of a problem in the tropics where the stylos are well adapted to both low soil fertility and periods of heavy grazing.

Soil fertility is important for the productivity and persistence of pastures. The productivity of grass-only pastures depends on the soil fertility (and any fertiliser applications) and their persistence is also strongly influenced by soil fertility.

Although phosphorus deficiency can be overcome by fertiliser application, superphosphate (and other fertilisers) are generally too expensive for use on pastures for beef cattle.

### *5.4.3 Legume dominance.*

The success of the stylos, especially the shrubby stylos like Seca, has created some pastures where the grass component is either grazed out and/or out-competed. Legume contents of 70-90% are not unusual in pastures that are older than 6-10 years, especially on lighter country where stylos do best. This can create problems for the condition of the surface soil, as there is often low levels of soil cover particularly at the end of the dormant season. On some soils, sheet erosion is accelerated.

Legume dominance also accelerates the process of soil acidification. Soil acidification is a natural process but the rate can be greatly accelerated where excess N is leached through the soil. Decreases in soil pH under temperate legume-based pastures in southern Australia have been known for some time but have been detected only recently under stylo pastures in the tropics. Although measured reductions in pH under grazed pastures have not been sufficient to affect pasture production yet, the results suggest that it is only a matter of time. Impacts of low pH include increases in soluble aluminium and manganese in soil to possibly toxic levels, altered availability of soil nutrients, and breakdown of clay minerals. Such effects will reduce productivity and probably alter pasture composition. Greatest risk of acidification is with light textured soils, because of their low capacity to buffer changes in pH. Ironically, these soils often grow the best stylo pastures.

Legume-dominant pastures may increase the risk of periods of feed shortage, particularly if the legume component of the pasture is likely to drop its leaf in response to dry or cold conditions. Lack of perennial grass can also reduce animal performance in the early part of the growing season, as the legume may not produce as rapid a flush of growth in response to the first rains.

The balance of stylo and grass in pastures can be managed by a combination of:

- Sowing introduced grasses like sabi grass or buffel that may compete better with stylo;
- Using fire on an infrequent basis to maintain the stylo content between 30-60%. Fire should be used after the pasture is well established and before the grass content of the pasture drops below 60%;
- Regular spelling of pasture in the early growing season encourages desirable native and introduced grasses.

### *5.4.4 Localised effects on diversity and landscape health.*

Sown pastures are generally less diverse than native pastures. This may reduce their stability: sown pastures are susceptible to loss of the main legume or grass. This could occur because of inappropriate management or because of a pest or disease. An example of the latter occurred when anthracnose devastated Townsville stylo pastures during the 1970's.

Sown pastures may affect both nutrient cycling and the water cycle, with consequences for trees growing in the pasture. For example, trees in sown pastures often suffer a greater incidence and severity of die-back compared to trees in native pastures. This is likely due to increased soil fertility making the foliage more attractive to insect attack. Increased incidence of tree-dieback may also be associated with increased competition for water during dry periods. This is more likely to occur with pasture species like the shrubby stylos which are deep-rooting and extract water from below 3-4 meters.

Not developing the whole property to sown pastures is one obvious means of managing these effects. In south-east Queensland, a guideline of limiting intensive pasture development to 30% of a property has been suggested, based on expert opinion and experience from intensively-developed areas in New South Wales. However, the effect of various levels and types of development have not been field-tested.

### *5.4.5 Weediness and off-site effects on diversity and landscape health.*

Introduced pasture species are attracting criticism for their impacts on biodiversity and landscape health, and a number have been listed as environmental weeds. Environmental weeds are species that invade native plant communities and cause changes to the vegetation structure (species composition and abundance) and/or the function of the ecosystem. These changes may result in a decline in habitat value for native plants and animals, reducing the area's value for conservation of bio-diversity. Possible effects of environmental weeds on native plant ecosystems include changed nutrient levels, altered fire regimes, competition, and changed drainage flows.

### *5.4.6 Toxicity problems.*

Toxicity problems with sub-tropical and tropical pasture species are rare. Leucaena has problems with mimosine toxicity, but a rumen bacteria is available which overcomes any problems. Several of the introduced grasses (eg, buffel grass, the setarias) contain high levels of soluble oxalate which can cause problems with horses: the oxalate interferes with calcium metabolism and causes a condition known as 'big head'. In the limited areas where temperate pastures do well, legumes such as lucerne cause a risk of bloat.

## 5.5 Which pasture species are suitable for my situation?

There are currently more than 150 tropical pasture cultivars registered or where applications for breeders rights have been granted, belonging to 70 tropical and subtropical species (37 grass species, 33 legume species). These vary region by region and the list here is not meant to encompass all species that could be used in every area. They are representative of the potential of sown pasture species.

### *5.5.1 Legumes*

**Shrubby stylo** (*Stylosanthes scabra*) - a perennial woody erect shrub suited to tropical and subtropical (north of 27°S) districts with 600-1600 mm of rain. Although most commonly sown on infertile sandy soils it can thrive on most other soils except waterlogged or heavy cracking clay soils. Shrubby stylo tolerates a wide range of grazing regimes. Fire and frost kill the top growth but plants can reshoot from the base or re-establish from seed. The most widely used cultivar is Seca which is resistant to the anthracnose strains currently present in Australia.

**Caribbean stylo** (*Stylosanthes hamata*) - a drought tolerant annual or short-lived perennial that grows well in tropical areas with 600-1700 mm of rain. It is adapted to a wide range of infertile sandy-surfaced and well-drained soils. It tolerates heavy grazing and has good seed production even under grazing. It has moderate resistance to anthracnose.

**Lablab** (*Lablab purpureus*) - a vigorous twining annual or short-lived perennial sown as a forage crop. It is large seeded and can be planted in a rough seed bed. It will grow on acid soils and responds well to superphosphate. Lablab produces a vigorous erect seedling which later develops long trailing stems bearing large leaves. Cattle may take some time to acquire a taste for lablab.

**American joint vetch** (*Aeschynomene americana*) - a vigorous erect plant that grows well in seasonally waterlogged country and tolerates low soil fertility. It seeds heavily and cattle readily spread the seed. Cultivar Glenn is an annual while cultivar Lee acts more as a perennial, and holds its leaf much better during winter than Glenn.

**Glycine** (*Neonotonia wightii*) - a species best adapted to fertile, well-drained scrub soils in areas with 850-1800 mm of rain. It cannot tolerate very acid soils or waterlogging. Glycine is a deep rooting plant with long stems that root down readily at the nodes. It is more cold tolerant than many other tropical legumes.

**Wynn cassia** (*Chamaecrista rotundifolia*) - does not tolerate heavy soils or waterlogging and is best planted on free-draining soils in tropical or sub-tropical areas. Wynn is early flowering with very high seed production. Although relatively unpalatable pastures based on Wynn have produced good cattle performance. Tends to drop its leaf during dry or cold periods. Legume dominance may be a problem in some areas, creating shortfalls in forage supply; this can be avoided through inclusion of competitive grass species in the sowing mix.

**Leucaena** *(Leucaena leucocephala)* - a deep-rooted perennial shrub legume that is able to produce new green leaf after the shallow rooted grasses have dried off. It is best suited to deep, well-drained and fertile soils of neutral to high pH in areas with more than 750 mm of rain. Leucaena has the highest feed value of any tropical legume and steers can consistently gain 300 kg per year with adequate leucaena. Leucaena is attacked by psyllids especially in hot humid conditions and its main use is now in the inland areas of central Queensland.

**Siratro** (*Macroptilium atropurpureum*) - grows well on a wide range of reasonably drained soils in areas with 800-1500 mm of rain. It is easily frosted with severe frost killing plants back to the crown. It is a vigorous twining legume which declines under heavy grazing.

**Fine stem stylo** (Stylosanthes hippocampoides) is recommended for light, well-drained soils in the frosty subtropics with annual rainfall of 700-1100 mm. It has been very successful on free-draining infertile granitic soils in the Burnett region of south-eastern Queensland. Although a specific inoculant is recommended, it seems to be rarely used as the plants do nodulate eventually. Its buried crown protects the plant from fire, frost and heavy grazing, making it well suited to extensive management. Even heavily grazed plants continue to flower over a long period, and the seed is spread through stock. Fine stem is quite palatable and tends to be grazed heavily. Fine stem has not been affected by anthracnose.

**Butterfly pea** (Clitoria ternetea) cv. Milgarra was released for grass-legumes pastures in the monsoonal regions with about 1300 mm annual rainfall and a strong dry season. It is a vigorous, persistent perennial plant with fine twining stems. It grows well on loams and clays, and can tolerate some short-term waterlogging. However, it is not suited to arid conditions, infertile sandy soils or to areas with frequent frosts, flooding or waterlogging. Butterfly pea is very palatable, and hence is susceptible to continuous heavy grazing. It persists best when grazed lightly during the wet season and heavily as stand-over feed in autumn during the dry.

**Desmanthus** (*Desmanthus virgatus*) is a perennial legume for clay soils receiving 550-750 mm rainfall. It is productive, palatable and drought-tolerant. Desmanthus is suited to both tropics and subtropics, being reasonably cold-tolerant, and although defoliated by heavy frosts, it will regrow from crowns once there is enough moisture. Desmanthus does not cause bloat. Desmanthus seed is small and should be treated to reduce the high proportion of hard seed. A specific rhizobium is needed. Three cultivars have been released, each will different flowering times - cv. Marc is short (30-60 cm) and early flowering; Bayamo is tall (95-135 cm) and flowers in the mid-season; Uman is middle height (40-100 cm) and late-flowering.

**Lucerne** (*Medicago sativa*) is the most tropical of the temperate legumes. It is an erect perennial with a low-set crown and an extremely deep root system, allowing it to be grown with as little as 550 mm of annual rainfall. Lucerne needs at least 30 cm of friable loam, and demands high fertility, being very responsive to phosphorus and sulphur; it may grow under slightly acid conditions if top-dressed with lime. Lucerne is quite widely used as a pasture plant in sub-coastal and inland subtropical areas. It combines with green panic, buffel grass and Rhodes grass, but persists for only a few years despite rotational grazing of a system of two weeks grazing and six weeks resting. It is usually lost within a year under continuous grazing. Persistence is a problem in the subtropics because lucerne is attacked by many leaf and root diseases and by insect pests. Many cultivars are available but the locally bred Trifecta and Sequel have accounted for more than 80% of new plantings from certified seed in Queensland since 1985.

A number of annual **medics – barrel** (*Medicago truncatula*), **burr** (*M. polymorpha*) and **snail** (*M. scutelata*) – are important in colder subtropical areas with reasonable winter and spring rainfall. Medics grow best during the warmer conditions of autumn and spring, but a wet autumn will give a good bulk of feed for winter. Medics are adapted to a Mediterranean climate with dry summers; they survive wet summers in the subtropics because of their hard seed, but with enough softening to allow regeneration in autumn. A number of cultivars are available in each species.

### 5.5.2 Grasses

**Buffel grass** (*Cenchrus ciliaris*) - a hardy, drought tolerant, persistent perennial grass for regions with 300-1000 mm of rain. It grows on a variety of soils but prefers lighter textured, reasonably fertile soils. However it is sensitive to waterlogging and has only moderate salt tolerance. Buffel is well suited to the poorer types of softwood scrub, the harder brigalow country, gidyea country and more fertile forest soils. It can withstand heavy grazing and grows rapidly after the first rains of the wet season. Buffel grass has low sodium levels but a moderately high oxalate content that can cause 'big head' in horses. There are a number of cultivars of variable habit and height.

**Silk sorghum** (*Sorghum alum sp)* - a vigorous short-lived perennial growing to 3 metres under good conditions. It is best adapted to sub-tropical areas with 500-900 mm of rain. Silk needs good soil fertility. It is not particularly frost tolerant but comes away early in spring. The large seed makes establishment easy and provides quick feed. Silk's main use is as a short-lived pioneer sown with longer-lived species.

**Purple pigeon grass** (*Setaria incrassat)* - an erect grass suitable for areas with 500-800 mm of rain. It is drought- but not frost-tolerant. It is well accepted by cattle but less palatable than green panic. Purple pigeon grass is well adapted to cracking clay soils; it has a large seed and establishes reliably on these soils in contrast to most other grasses.

**Rhodes grass** (*Chloris gayana*) - a tufted perennial grass that produces long runners that root strongly at the nodes covering the ground rapidly and giving good ground cover. It grows on a variety of soils in the 700-1000 mm rainfall zone. It is quite salt tolerant. A number of cultivars are available which vary is size and morphology, flowering time, drought tolerance, palatability, and soil fertility requirements.

**Green panic** (*Panicum maximum* var. *trichoglume*) - responds rapidly after rain, is fairly drought tolerant, and is used in areas with 550-1700 mm of rain. It is very responsive to nutrients and grows best on friable scrub soils and self-mulching heavy clays. Green panic is very palatable and is usually preferentially grazed in mixed swards. It has some shade tolerance and is often found growing under trees.

**Signal grass** (*Brachiaria decumbens*) - a low-growing perennial with trailing stems that root at the nodes forming a dense ground cover. It has some drought and cold tolerance and is well adapted to a wide range of soils in areas with more than 1000 mm of rain. It cannot tolerate waterlogging for more than a short time. The dense cover of signal grass prevents good compatibility with twining or erect legumes.

**Setaria** (*Setaria sphacelata var. sericea)* - among the most cold-tolerant of the tropical grasses and is commonly grown in higher rainfall coastal districts of the sub-tropics. It requires reasonable soil fertility but tolerates short-term waterlogging. Setaria is well accepted by cattle but has a low sodium concentration and high oxalate concentration. There are a number of cultivars: Narok and Solander are more frost tolerant than other cultivars.

**Makarikari grass** (*Panicum coloratum var. makarikatiense*) has bluish green leaves, a deep fibrous root system that makes it drought resistant, some salt tolerance, remains green and palatable during winter, and is adapted to a range of soils including heavier clays. Cv. Bambatsi is an erect tussock grass.

**Indian bluegrass** or **Indian couch grass** (*Bothriochloa pertusa*) is a strongly stoloniferous grass that has naturalised over large areas between Bowen and Charters Towers in north Queensland. Indian couch has invaded because of heavy grazing of the native pastures and has provided good ground cover and reasonable grazing. The **Bowen** strain of Indian couch can flower within one month of rain, and seed is spread by wind. Bowen is the least vigourous strain, but the best naturaliser; **Yeppoon** strain is taller, later flowering and more suited to cattle grazing. **Dawson** is a very late-flowering strain for lawn turf.

**Sabi grass** (*Urochloa mosambicensis*) is a tufted perennial grass naturalised in tropical areas receiving 500-1200 mm of rain. It is drought resistant and grows well after rain but has poor frost tolerance. Sabi grass is adapted to a wide range of soils but responds well to good fertility. It is palatable but withstands close grazing and combines well with legumes. A creeping urochloa selected for rehabilitating mine spoils has been released as cv. **Saraji.** This could also be a useful grazing species, although it appears to become less vigorous with time.

### *5.5.3 Choosing the most suitable pasture species*

There are often a number of species or cultivars available that are suitable for particular situations - see the list and descriptions above. The most suitable species or cultivar for any one situation will depend on:

- Climate (rainfall, frost)
- Soil type including drainage and salt content
- Need for short- or long-term pasture
- Likely sowing method
- Herbage quality required
- Seed costs
- Fertiliser requirements
- Existing pasture and whether over-sowing or replacing pasture
- Management requirements
- Need for protection against soil erosion
- *Rhizobium* requirements for legumes, to ensure that N fixation can occur

## 5.6 What are the management requirements of sown pastures

In general sown pastures require more intense management than native pastures to realise their full potential and ensure a good economic return on the investment.

- Selecting most suitable land types for sown pastures - best returns are gained from higher fertility country.
- Meeting establishment needs - choose a suitable sowing method that will maximise establishment.
- On-going management - grazing and fire management, managing pasture rundown and providing mineral supplementation

### *5.6.1 Selecting suitable paddocks and land types for use of different species*

Fertile soils are attractive for pasture development as they are more likely to provide all the necessary nutrients and not require fertiliser application. Unless the grass sowing is part of a rehabilitation program on degraded land, grass-only pastures should only be considered for fertile conditions, as soil nitrogen supply will determine the productivity and financial returns.

Stylos can grow productive pastures on poor soils. Where soil phosphorus levels are very low (<3 ppm) even stylo growth is poor and some superphosphate is needed. With 4-10 ppm stylo growth is adequate without fertiliser application (although they are increased further with fertiliser). On country with soil P above 10 ppm, stylos will grow to their potential. Light textured soils are at greatest risk of acidification under stylo pastures, due to low capacity to buffer changes in pH, so the management strategy must consider ways of maintaining perennial grasses in the pasture.

The condition of the soil surface is important for over-sown legumes. Establishment is likely to be lower (especially if germination conditions are poor) on hard setting soils than on soils with a loose surface.

Cracking clay soils pose problems for establishment of grasses and for both establishment and persistence of legumes. Small grass and legume seed should not be sown too deep or the top layer of soil can dry out too rapidly. Larger seeded grasses can be sown deeper where the moisture supply is more assured. Purple pigeon grass and creeping bluegrass establish better on cracking clay soils than many other species.

There are many suggested reasons for the failure of tropical legumes to persist on heavy clay soils – drought stress, failure to re-establish, waterlogging, alkalinity, root disruption by the soil cracking, ineffective *Rhizobium* symbioses, grass competition, sub-soil salinity, and disease. Several cultivars of Desmanthus have been released to help fill this need for legumes adapted to clay soils and there are shrubby stylos also suited to this role.

### *5.6.2 Establishment of sown pastures*

The most important factors in establishing pastures are:

(a) eliminating or reducing competition from other plants.
(b) providing good contact between the seed and moist soil.

Methods which improve either or both of these will improve the reliability and speed of establishment. In general, methods that give the best establishment are the most expensive and the decision must be made about an acceptable balance of costs and risks.

Establishment can be divided into two phases – seed germination and emergence, and seedling growth and survival.

- **Seed germination and emergence.** For a seed to germinate it must take in enough water – this is a balance between uptake of water from the soil and loss to the atmosphere. Uptake is greater with increased seed-soil contact (e.g. on a cultivated seed-bed) while surface cover reduces the rate of water loss.
- **Seedling growth and survival**. This depends on the availability of light, water and nutrients. While species vary in their requirements, competition can drastically reduce the levels of all factors and have an overriding impact on growth and survival.

Having chosen the most suitable species and made sure that high quality seed is available, it is necessary to prepare the most suitable seedbed. Some successful sowings of pastures have been made with the following seedbed preparations - these are apart from full seedbed preparation, direct drilling and the like.

- **Strip planting** - pasture is sown in strips to cover 25-50% of the area, mainly as a cost saving measure. The species must then spread to the unsown areas.
- **Band-seeding** - band-seeding is a specialised form of sod-seeding using herbicide to control competition; it provides more precise seed placement than other over-sowing techniques.
- **Surface broadcasting or aerial seeding** - surface broadcasting whether from the ground or air simply involves dropping the seed on the soil surface without soil disturbance, often following fire or heavy grazing to reduce the existing dry pasture. Surface broadcasting is cheap but gives unreliable establishment largely due to competition aggravated by dry spells. Most success has been achieved in tropical areas, probably because dry spells during the wet season are less common and the existing grass stands are weaker.
- **Crocodile ripper** - this machine can roughly prepare a seedbed and reseed; it is especially suitable for sowing degraded rough country as a means of rehabilitation.

### *5.6.3 On-going management of sown pastures*

There are four main factors in the on-going management of sown pastures:

- grazing management
- fire management
- managing pasture rundown
- need for mineral supplementation

**Grazing management**. Grazing management is important throughout the life of the pasture. The aim of grazing during establishment is to maximise the growth and seed-set of the sown species and minimise competition from other plant species. Some grazing management guidelines are suggested in Table 3, but each establishing pasture should be treated on its merits.

**Table 3. Grazing management guidelines for establishing pastures, based on growth form and palatability.**

| | Habit and palatability | Recommendation |
|---|---|---|
| **Grasses** | All | Spell until seeded |
| **Legumes** | Low-growing, palatable (Caribbean stylo) | Graze early, spell at flowering |
| | Low-growing, unpalatable (Wynn cassia) | Graze continuously |
| | Erect, palatable (American joint vetch) | Graze mid-season, spell at flowering |
| | Erect, semi-palatable (Shrubby stylo) | Graze continuously (tropics)<br>Spell at flowering (subtropics) |
| | Twining, palatable (Siratro, Centro) | Spell at flowering |
| | Twining, unpalatable (Calopo) | Graze continuously |

Although in sown pastures may be more tolerant of grazing than native pastures, they can also be overgrazed – this is particularly true for palatable species (e.g. green panic) and twining legumes (e.g. Siratro). Different legumes respond differently to grazing pressure – the twining legumes decline if grazed heavily while low-growing legumes often decline if the pasture is grazed lightly. In mixed pastures containing Verano and Seca growing near Charters Towers, the proportion of Seca in the pasture was much less sensitive to grazing pressure than Verano (Figure 7). The proportion of Verano was low in lightly grazed stands but increased as grazing pressure increased (as indicated by decreasing level of herbage allowance).

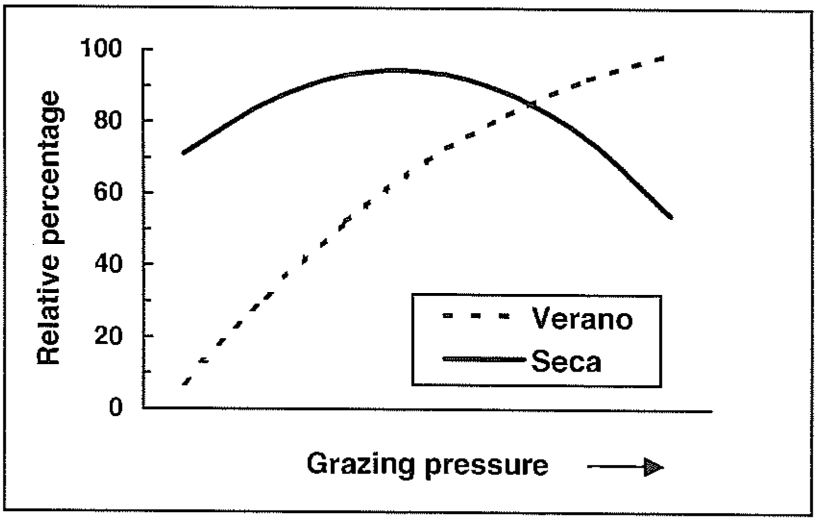



**Figure 7. Relationships between grazing pressure and the relative proportions of Verano and Seca in pastures growing near Charters Towers.**

In mixed legume-grass pastures the nitrogen supply from legumes is critical both directly for animal diets, and indirectly as a boost to the growth of the associated grasses, so maintaining a productive legume is an important aim of grazing management. Stocking rate should be managed to both encourage the more desirable species and to make most efficient use of pasture. Small areas of sown pasture may be best used in a grazing system that includes other pasture types. In this way, the pastures can be spelled at critical times and utilised to coincide with their greatest impact on animal performance. An example is the use of leucaena pastures in combination with native or other grass-dominant pastures: the leucaena pasture may be spelled for most of the growing season when the other pastures are of relatively high quality and then used in combination with the grass pasture to boost diet quality into the dormant season.

**Fire management.** Sown pastures tend to be burnt less frequently than native pasture, particularly where the pasture contains a legume.

In general, the sown grasses (like the native grasses) are tolerant of fire but sown legumes are damaged to different degrees – some are killed, while others will resprout from the base. Two examples of a role for fire in managing sown pastures are as follows.

Firstly, in a grass-only pasture during a good growing season there may not be sufficient animals to utilise available feed and a large amount of dry herbage may accumulate. This can be burnt to remove the dry herbage and make new growth more available to animals. Secondly, where Seca has dominated a pasture fire can be used to partially reduce the density and growth of the legume, reducing competition and allowing the perennial grasses to build-up in the pasture.

**Managing pasture rundown.** One options for managing pasture rundown are to do nothing, ie, accept the situation. Alternatively, there are options for limiting the rate of rundown by stimulating available soil N. Options include:

- crop/pasture rotations;
- sowing legumes into the pasture;
- renovating the pasture mechanically (the greater the disturbance of the soil, the greater the release of N, but the longer the time for pasture density to be restored);
- burning (to reduce tie-up of N in litter); and
- nitrogen fertiliser applications (this is uncommon due to the high costs associated with having to apply N every year.)

**Need for mineral supplementation.** In some situations, deficiencies of minerals may limit the production from sown pastures, and these should be overcome with supplementation. The most important example is the need for P supplements for cattle grazing stylo-based pasture on low P soils (<5 ppm). The use of sown pastures, especially legumes, will reduce the need for dry-season supplementation with urea or other sources of N.

### 5.7 Assessing the financial impact of using sown pastures

The final decision on whether to use sown pasture, as well as questions on how much area to sow and with which method, will largely depend on the projected economic outcomes of different options. Despite the significant improvement in animal production that can be achieved from introduced pastures, their high cost and unreliability of establishment has limited their widespread use.

The likely financial returns from a pasture improvement program can be estimated by comparing the costs (both the initial and ongoing) and expected returns. Costs can generally be determined with some degree of certainty but quantifying benefits can be difficult.

The following principles are relevant:

- the higher the costs the more substantial must be the ensuing productivity gains to warrant it;
- discounting favours options whose benefits accrue soon after the expenditure is incurred, unless the subsequent productivity gains from alternative options are particularly high;
- options with consistent and long-lived benefits are preferable to those with inconsistent and short-lived benefits;
- the financial benefit is a function of both the productivity gain and the value of the product;
- the economic value of a long-term pasture development project is substantially affected by the availability of alternative investments that are considered to be both profitable and attractive.

Establishment costs are the largest part of the costs of sown pastures - although increasing establishment inputs can increase the probability of successful establishment they can add a financial burden that may be unacceptable for the property as a whole.

Indicative costs for two different forms of pasture establishment are shown in Table 4. You need to obtain local up-dated quotes for your own situation.

**Table 4. Typical costs ($/ha) for establishing a fertilised grass-legume pasture by two methods.**

| | **Cultivated seedbed** | **Over-sown** |
|---|---|---|
| Legume seed | 25 | 25 |
| Grass seed | 18 | |
| Fertiliser | 33 | 33 |
| Labour | 35 | 10 |
| Tractor and machinery | 24 | 6 |
| **Total direct costs** | **135** | **74** |
| Interest on capital | 17 | 3 |
| Tractor and implement | 28 | 4 |
| **Total indirect costs** | **45** | **7** |
| **Total costs** | **180** | **81** |

Cultivated seedbed = using offset discs (two passes) and a seed drill,
Oversown = a single pass ground application with a fertiliser spreader into uncultivated native pasture .

Where large areas are involved aerial seeding can reduce the application costs compared to ground broadcasting. These costs do not include any tree clearing costs – if clearing is necessary, costs could be 2-4 times higher.

# 6. Managing trees-grass balance

## 6.1 Why is the tree-grass balance important?

The majority of grazing land in the northern half of Australia is woodland. Woodlands have a mix of two distinct plant types – woody species and herbaceous species (grasses, forbs) – and both types are important. On grazing lands, the main economic value of woodlands is derived from the grass layer. Although some edible trees and shrubs occur, most animal feed comes from the herbaceous layer and most interest in woodland management has been in reducing the tree layer to favour pasture production.

In some regions, thinning or clearing of the woodlands to stimulate greater grass growth has been a common practice. At the same time, there appears to have been a change in the structure of woodlands in most regions; changed fire regimes since European settlement (and particularly in the last 40-50 years) appear to have caused a build-up or 'thickening' of woody plants (Figure 1). This trend has caused concern about reduced grass growth and carrying capacity. Even areas of semi-arid shrublands and grasslands show evidence of woody plant thickening and invasion.

**Figure 1. An example of woodland thickening: an old and a recent photo of the same site in mulga country of south-west Queensland.**

In recent years, tree clearing has become highly controversial in light of emerging national and international pressures to stop the decline of native vegetation, to prevent and/or remedy erosion and salinity problems, and to increase fixation and storage of carbon by trees as a means of addressing climate change. There is also growing interest in the benefits of trees for land condition and pasture quality, eg, as nutrient pumps.

Managing the tree-grass balance can therefore enhance one of the major gateways towards sustainable beef production: rainfall use efficiency. Woodland management can improve RUE through reducing competition from woody plants, by optimising any positive effects of trees on RUE, and by minimising risks of dryland salinity.

Managing the tree-grass balance can also affect diet quality. Nutrient content of pasture can be higher under tree canopies, while the extra grass growth from removing trees may dilute the limited supply of soil nutrients. These effects, although difficult to quantify for every situation, should be considered in determining the woodland management strategy that best meets production goals.

Ease of mustering is also related to woodland management. Visibility and access is reduced by woodland thickening (caused mainly by lack of fire), and by the dense regrowth that often follows poorly-managed clearing of trees.

It is important to look at the ecology of woodlands: how the plant species interact and the effects on soil and animals. Some aspects are well understood while other aspects are more uncertain. We will use this understanding to develop a tree-grass or woodland management strategy that is consistent with production and sustainability goals. This strategy will be strongly linked with the fire management strategy which, in turn, is linked strongly to the grazing management strategy.

Of course, any strategy or plan that involves mechanical or chemical treatment of woody species must be in compliance with relevant legislation and regulatory requirements. The latter are commonly based on conserving 'reasonable' areas of different plant communities (or 'regional ecosystems') across the region and on minimising the risk of future problems with salinity.

### *6.1.1 What makes up woodlands?*

The most common woodlands are dominated by eucalypts (*Eucalyptus* and *Corymbia* spp.) and sometimes by tea-tree (*Melaleuca* spp). The herbaceous species are predominantly perennial tussock grasses (e.g. black speargrass, bluegrasses, golden beard grass) but also include annual grasses and annual and perennial forbs (including native legumes). Shrubs, both native (e.g. wattles, currant bush) and exotic (e.g. parkinsonia, chinee apple), also occur. Acacia woodlands and forests occur over smaller areas but are often significant for productivity; examples include brigalow, gidgee, and blackwood. These often form a thick shrub canopy and therefore support only a sparse herbaceous layer in their natural state.

The density and size of woody plants determines their competitive effect on pasture: competition from tress is directly related to their leaf area, which determines the amount of water they will use. Tree canopies are difficult to measure or estimate, but they are related to a measure called tree basal area (TBA). TBA accounts for both size and density of trees. It represents the sum of the stumps' areas (for live trees) in square meters per ha (Figure 2).

(a)

(b)

(c)

**Figure 2. Examples of different tree basal areas (TBA), 4 $m^2$/ha (a), 8 $m^2$/ha (b), and 15 $m^2$/ha (c).**

### *6.1.2 What controls the 'natural' density of trees?*

**Importance of climate and fire.** Woody plants tend to dominate the vegetation in most parts of the world. Woodlands occur in intermediate rainfall zones. In wetter areas, forests are common (tree canopies are denser and there is little grass), while in deserts there are few or no trees, and grasses may be evergreen e.g. spinifex.

In woodland areas, the trees are prevented from dominating by the seasonal drought that occurs each year, the effects of which may be reinforced by fire and grazing. Trees in woodlands do not have sufficient water during the dry season to support a full leaf canopy. The restricted canopy is then unable to fully exploit the water available during the wet season, leaving soil resources (water, nutrients) for the grasses to use.

The 'natural' density of trees in a woodland is therefore controlled, in the first instance, by the climate of the area. Specifically, tree density will be related to the soil moisture available during most dry seasons. This, in combination with evaporative demand, sets the maximum density of trees that can survive, and denser stands will competitively thin to this level. Competition for water from adult trees suppresses growth of tree seedlings and saplings.

Thus, areas with greater water supply or lower demand (eg. higher rainfall areas, areas with deeper soils, run-on areas, areas with lower evaporation rates) will have higher densities of trees. In eucalypt woodlands, tree densities tend to decline as soils increase in clay content; this is likely due to the more extreme moisture stress on these soils during the dry season. All these factors vary from region to region and even across a landscape. Typically, lowest tree densities occur on ridge tops in arid, inland areas and highest densities occur on deep soils in coastal areas.

Fire is a factor which will also influence the 'natural' density of woody plants, especially the density of the mid-story or shrubby layer. Most grazing lands have a long history of fire incidence. Fire limits the regeneration and growth of trees. Seedlings may be killed or their growth may be reduced, keeping them small and more vulnerable to grass competition and grazing. Both anecdotal and experimental observations show that fire can have quite large effects on woodland structure, and that the absence of fire generally encourages woody plants at the expense of grass. So, while climate affects the broader longer-term patterns of tree density, there is a major interaction with fire management.

**Turnover of adult trees and seedlings.** The mix of trees/shrubs and grasses is dynamic and continuously changing in response to environmental (e.g. drought) and management factors (e.g. fire, clearing).

There is usually a low rate of turnover in tree populations, as annual mortality rates for adult trees are usually low. However, there may be periods of much higher death rates. For example, about 30% of tree basal area (a measure of both number and size of plants) was lost to tree death in parts of north Queensland during the extreme drought of the early 1990's. In other parts of Australia, native tree dieback (progressive, usually protracted, dying back of branches often ending in tree death) has become a major concern, particularly in long-settled, intensively-farmed areas. Many factors are involved in tree dieback including the amount of clearing, weather conditions, land use and management, salinity, insect populations, livestock grazing, bird populations, waterlogging, and pathogens. A major cause of tree dieback is repeated defoliation by leaf-eating and leaf-sucking insects.

Most woodlands have a unexpectedly high population of saplings and suppressed seedlings which will grow quickly once competition from the adult trees is reduced.

Successful establishment of tree seedlings occurs irregularly: it is controlled by rainfall (limiting seedling germination and establishment), fire (limiting growth to adult size), and competition from existing trees and from the pasture. Seed dispersal by eucalypts is limited and is likely to be less than 25-30 m from the parent tree. Most seedlings will therefore establish near existing trees. When establishment does occur, it is likely to lead to a denser population than the area can support and there will be some natural thinning of seedlings and saplings.

Shrubs and small trees, particularly wattles, provide a shrubby understorey in most eucalypt woodlands, and especially on the more infertile soils. It appears that most wattles are "fire weeds", with an initial mass germination following disturbance. The population then declines (rapidly at first) with few plants living more than 30 years (whereas eucalypts live for a hundred years or more). Maximum seed production from individual wattle plants occurs 8-12 years after establishment but there may be large soil seed banks for many years. Annual or biennial burning tends to eliminate wattles, since it kills seedlings and removes plants before they set seed.

### *6.1.3 How do trees affect pasture?*

Trees can have both positive and negative effects on the grassy layer (Figure 3), and these effects are caused by:

- rainfall interception;
- shading;
- root competition;
- micro-environment changes and
- effects on soil condition.

Figure 4 shows how these effects are expressed in eucalypt woodland in a sub-tropical environment in relation to distance from the base of a tree.

**Rainfall interception.** Trees intercept rainfall and "store" part of it in the canopy, from where it evaporates. Thus, a proportion of rainfall is not available for growth. In most woodlands, loss of moisture in this way is of minor importance.

**Shading.** Shading may reduce pasture growth. Impacts depend on the density of the leaf canopy (i.e. they would be higher in the denser Acacia woodlands than eucalypt woodlands) and the overall level of radiation. Overall, shading is of minor importance given the generally sparse canopies of eucalypt woodlands and the levels of radiation.

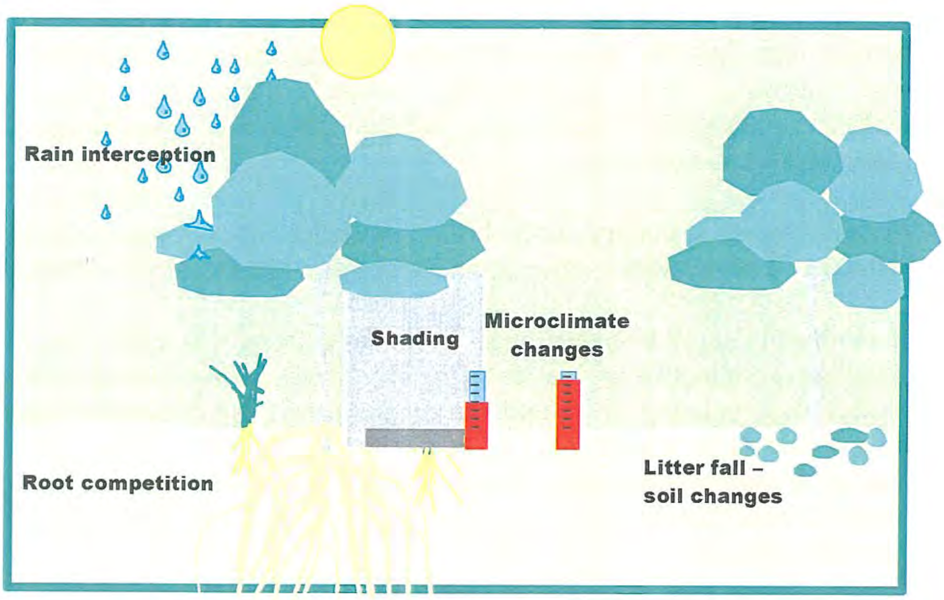



**Figure 3. The various ways that woody plants interact with the grassy layer.**

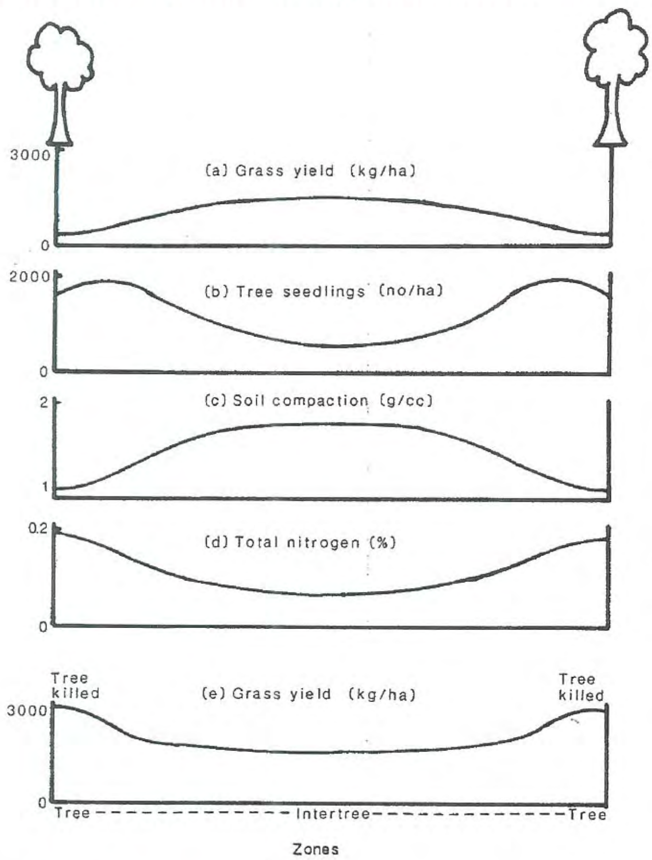



**Figure 4. The effects of distance from the base of a tree on the net effect of tree-grass interactions for eucalypt woodland in the sub-tropics.**

**Root competition.** The most important mechanism through which trees affect the grass layer is competition for nutrients and water. Both trees and grasses have roots in the surface soil (<50cm) and in the sub-soil. However, grasses have a greater proportion of their roots in the surface soil and the growth of grasses is closely tied to the water supply in the topsoil. Competition for water will be greatest in drier seasons because, in wet years, more soil water is available to meet the demands of both trees and grass.

There is a wide geographic variation in the availability of water during the wet season. In the northern monsoonal areas rainfall is relatively reliable, wet season rainfall is high and usually not broken by dry spells; as a result, competition for water is relatively low. In contrast, rainfall in the sub-tropics is less reliable, often lower, and dry spells are common; as a result competition from trees is usually more intense. Trees also compete more strongly with grass for water on shallow compared to deep soils.

**Micro-environment changes.** Trees can lower the temperature and evaporative demand experienced by grasses. If this raises the water status of the grasses and other factors are not limiting growth, this can increase grass growth compared to exposed areas. Trees may also reduce frost impacts.

These micro-environmental effects are probably only minor in most woodlands, compared to the competitive effect. However, there is recent evidence showing that narrow strips of brigalow scrub, interspersed amongst cleared strips and aligned perpendicular to the general wind direction, greatly reduce temperatures in the pasture sward. This is likely to promote a longer growing season. Figure 5 shows how tree or shrub belts can affect wind speed, one aspect of micro-climate.

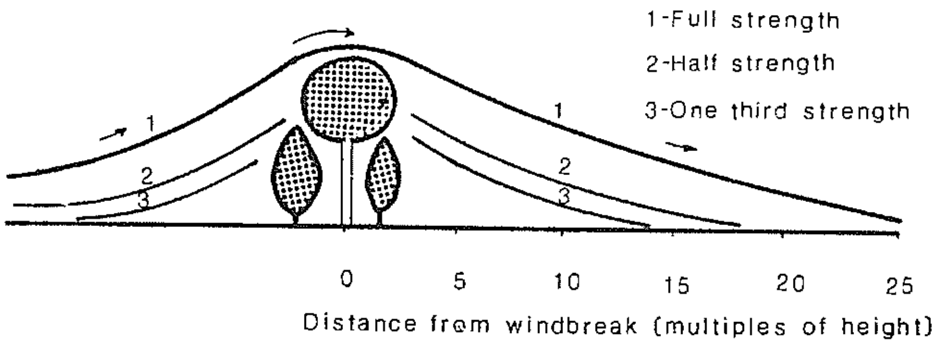



**Figure 5. Influence of a tree clump on micro-climate.**

**Soil condition.** The soils under tree canopies can have higher nutrient and organic matter levels and better physical characteristics, leading to improved water infiltration and storage. Several mechanisms have been proposed for these effects:

- Trees act as nutrient pumps drawing nutrients from deep horizons and from beyond the canopy and depositing them beneath the canopy via litter-fall.
- Tree canopies trap dust which washes off the leaves into the soil beneath the canopy.
- Trees provide shade, cover and nesting for animals, which add nutrients via dung deposition.
- Trees provide more favourable soil conditions for soil fauna, stimulating nutrient cycling.

These benefits for soil condition are most obvious in woodlands with widely-spaced, deep-rooted trees on infertile soils. These effects are also very noticeable after killing or removal of trees and shrubs (see Figure 4). The area around the tree or shrub often produces much more pasture growth than areas not associated with tree or shrub canopies: the competitive effect of the woody plant has been removed and the pasture can take advantage of the improved soil condition.

**Net impacts of trees on the grassy layer**. The effect of trees on pasture growth depends on whether individual tress are having a competitive or stimulatory effect on pasture growth adjacent to the tree. Figure 6 shows the common case in eucalypt woodland in which there is a net competitive effect. This means that trees have a net competitive effect on pasture growth at all tree densities, as shown in Figure 6a. Maximum pasture growth occurs with no trees and grass yields initially decline rapidly as tree biomass increases, but the rate of decline falls with further increases in tree biomass. A similar relationship occurs in mulga and brigalow woodlands.

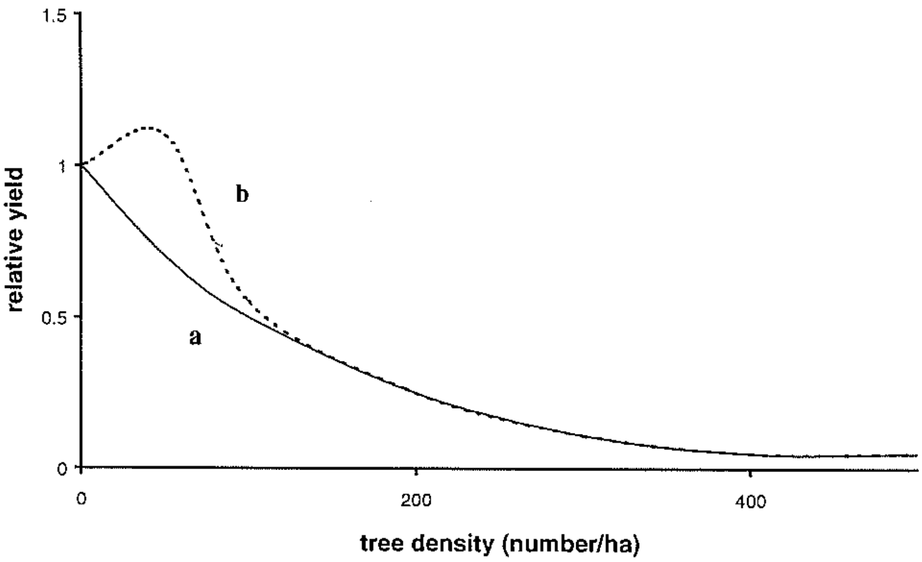



**Figure 6. General relationship between pasture yield (relative to pasture yield with no trees) for (a) the situation where individual trees have a net competitive effect on pasture growth and for (b) the situation where individual tress have a net stimulatory effect on pasture growth.**

The degree of curvature in this relationship (Figure 7) indicates the intensity of tree-grass competition, and depends on climate, land type, and pasture composition – the relationship can be nearly linear on highly productive sites or in wet years at less productive sites, and more concave on less productive sites and in drier years. In tropical woodlands, there is generally less intense competition between trees and pasture compared to subtropical woodlands. This is due to the more intense competition for soil moisture between trees and grass in sub-tropical areas.

In some situations, eg, with leguminous trees, low densities of trees may stimulate pasture growth. However, as density increases further, competition will override stimulatory effects and pasture growth will decline (Figure 6b).

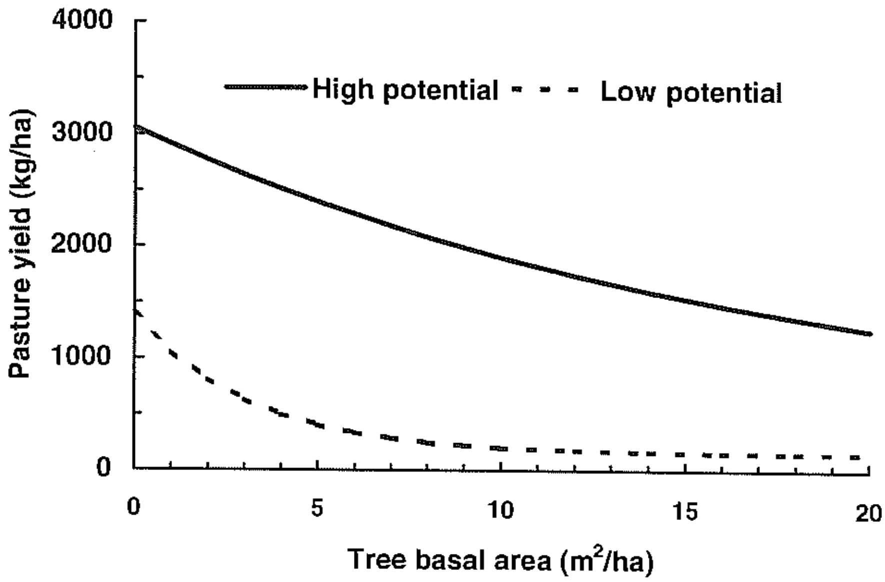



**Figure 7. The relationship between pasture growth and tree density for a fertile land type (high potential growth) and an infertile land type (low potential growth) in central Queensland.**

## 6.2 How can managing the tree-grass balance improve land condition?

Woodland management can improve land condition by reducing density of woody plants, thereby increasing the RUE of pasture. This can be achieved by:

- Clearing or thinning the woodland by mechanical or chemical methods
- Using fire to control the balance of woody plants and pasture

Carrying capacity can be increased by these options, the size of the improvement varying with land type, initial density of woody plants and other factors.

Risk factors also need to be managed to ensure that the woodland management strategy does not threaten land condition or landscape health.

### *6.2.1 Clearing or thinning woodland*

**Effect on pasture growth.** Clearing eucalypt woodlands increase native pasture yields, but the increase can vary from 50% to 500%. Effects depend on the climate (monsoon tropics, dry tropics, sub-tropics), the pre-clearing tree basal area (see Figure 6), the extent of thinning or clearing, the land type, variation in rainfall, and the amount of woody regrowth. Figure 8 shows an example of the effect of killing trees on pasture yield for country near Charters Towers. Note the variation in response from year to year, with the largest responses during the dry years of the mid 1980's.

Responses to tree removal are due mainly to increased availability of water and nutrients for pasture growth. Water supply is likely to be the main factor in most regions, but nutrient supply could also be enhanced by the addition of nutrients from decomposing tree residues, and the better soil condition often associated with tree canopies.

In some tropical regions where competition from trees for water is not great, pasture growth responses will be mainly due to less competition for nutrients, especially N. In general, responses to tree removal are greatest in the sub-tropics and least in the monsoon tropics, reflecting the amount and reliability of soil water during the wet season.

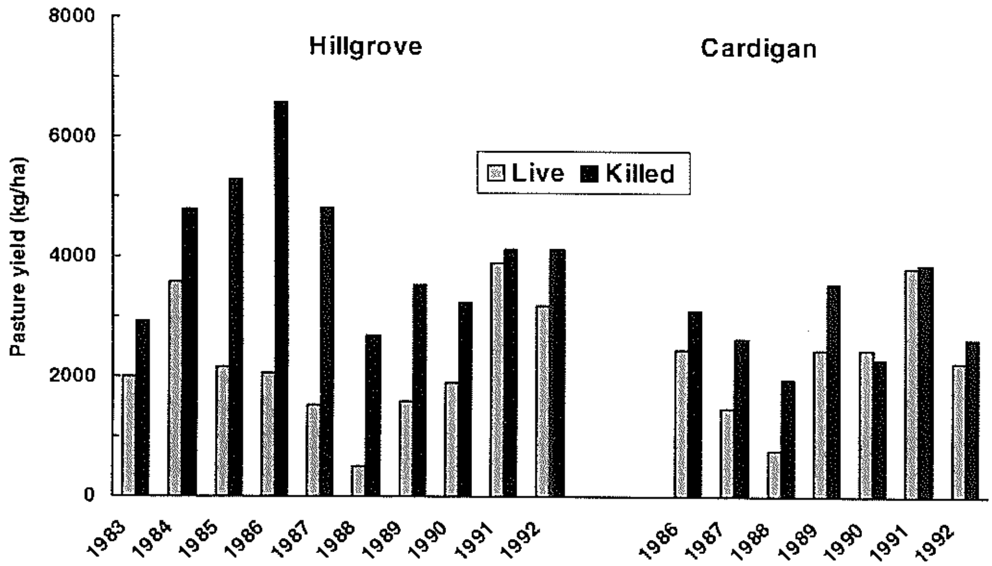



**Figure 8. Pasture growth from uncleared country (trees live) and cleared country (trees killed) for both basalt country (Hillgrove) and goldfields country (Cardigan).**

At any one site yield responses vary from year to year depending on rainfall distribution. Percentage responses to clearing are smaller during years when rainfall is well distributed and water is non-limiting during the growing season than years when the growing season is interrupted by dry periods (Figure 8).

The acacia woodlands (brigalow, gidgee, blackwood) are attractive for clearing and pasture development. Herbage production is very low in uncleared Acacia woodlands due to the dense tree canopies and sparse grass layer. However, soil fertility is generally higher than in most eucalypt woodlands and when the trees are removed and suitable species sown (e.g. buffel grass), highly productive pastures result.

Just as mature trees reduce grass growth so does regrowth with impacts dependent on the leaf area of the woody plants. Similar relationships can be expected for regrowth as for mature trees but since small trees have a greater amount of leaf per unit basal area, regrowth will tend to be more competitive per unit of basal area.

**Effect on botanical composition**. Thinning and clearing of trees can result in changes to botanical composition of the pasture, but the effects are not consistent. For example, research in central Queensland found that, as tree density increased, the proportion of spear grass decreased and the proportion of panicums, paspalum, forbs and sedges increased. On the other hand, comparison of cleared versus uncleared country have not detected major changes in botanical composition. Any significant changes in the pasture were a result of differences in grazing pressure, not clearing.

### *6.2.2 Using fire to control the balance of woody plants and pasture*

One objective of using fire is to control the balance of woody plants and pasture. Regular fire will maintain a more open woodland structure (Figure 9), and is particularly successful for reducing the coverage of mid-storey shrubs and saplings. The benefit for pasture growth will depend on the initial tree basal area, the degree of suppression achieved with fire, and climate. Likely benefits can be estimated from the relationship between tree density and pasture growth.

In the absence of fire, the trend of woodland thickening is likely to continue, further reducing pasture growth. Therefore, there is a cost in not using fire.

In situations where woodland thickening is well advanced, the impact of a fire regime may take some years to realise. Very intense fires may be required initially to achieve any significant reduction in woody plant cover.

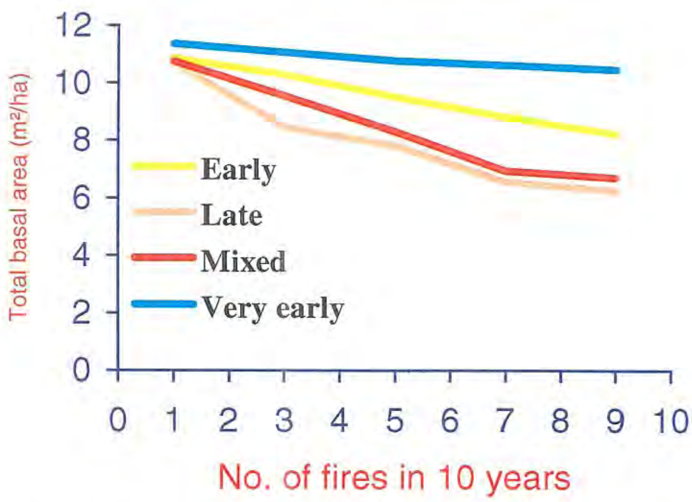



**Figure 9. The effect of frequency and timing of fires (very early dry to late dry season) on the tree basal area of tropical woodlands, as predicted by 'Flames', a computer model of tree-grass balance.**

### *6.2.3 Managing risk factors for land condition*

Risk factors for woodland management are mainly associated with clearing or thinning, and include:

- Lack of response to clearing or thinning
- Regrowth problems
- Nutrient decline
- Erosion risk
- Impacts on the water cycle and the risk of salinity
- Effects on conservation of native plants and animals

Inadequate use of fire is also a major risk for land condition, as it will increase the risk of woodland thickening.

**Lack of response to clearing or thinning.** For a given level of available water the grass growth response will be greatest where there is good pasture condition (high density of perennial grasses) on fertile soils. Responses to tree clearing may be disappointing on infertile soils or sites where pasture condition limits growth. Where the response to clearing is due to increased nutrient availability (from enhanced soil condition adjacent to the trees) rather than improved moisture supply, any responses may be short-term as the supply of nutrients will gradually return to previous levels.

Regrowth problems. Since a woodland with a significant tree layer is the natural state, areas from where the trees have been removed will tend to return to this state. Problems with regrowth are therefore common following tree clearing. This can result in a situation with more intense competition from woody plants than was the case prior to clearing. The regenerative capacity of the vegetation and the method of clearing influence the severity of regrowth problems. Regrowth problems can be reduced by:

- avoiding land types that are prone to major problems, eg, those with an understorey of wattles.
- using clearing techniques that minimise regrowth: eg, do not leave scattered trees over the paddock as this encourages seed dispersal over the whole area. Rather, woodland should be retained as large clumps or wide strips.
- having a grazing and fire strategy that ensures the area is regularly burnt following clearing: fire suppresses regrowth of most species. Where introduced pastures have been sown following clearing, it is best allow them to fully establish and set seed before using fire; pastures containing legumes should not be burnt until the plants have been able to build up a 'bank' of seed in the soil.

In some situations, regrowth will provide opportunities to reinstate woodland cover in areas that should not have been cleared in the first place., eg. due to salinity risk, importance as wildlife habitat, or value for shade and/or timber. It will take time for areas to recover their original composition and structure, and shrubs and more weedy species often dominate initial regrowth. Areas where it is desirable to retain regrowth should be identified on the property map and managed to encourage recovery of the original woodland .

**Decline in nutrient status and condition of soil.** There may be a slow and patchy decline in the nutrient status of soils, depending on the importance of trees in a particular woodland as nutrient pumps and/or 'conditioners' of the soil. This may reduce pasture growth and diet quality in the longer term, but the size of any impact is uncertain. The role of trees as nutrient pumps or as soil conditioners has not been studied adequately.

**Erosion risk.** Removal of trees does not necessarily increase erosion risk, as long as the method of tree removal does not reduce groundcover or concentrate water flow. The key factor in minimising erosion is maintaining ground-cover.

However, trees provide stability to stream banks. Tree roots increase the shear resistance of soils and by increasing the water use from soil reduce the risk of bank slumping and erosion. Trees also moderate conditions in streams.

**Impacts on the water cycle and the risk of salinity.** Removing trees from parts of the landscape will affect the water cycle, or hydrology, of the area. These changes can eventually lead to problems with salinity, called dryland salinity to distinguish it from the salinity problems associated with some irrigation practices. The risk of dryland salinity varies with a number of factors, including geology, the type of vegetation, and the location and relationship between recharge areas and discharge areas.

Salt problems arise when the presence of soluble salts in soils and waters adversely affects plant growth, degrades soil structure or limits the use that can be made of the water.

There is much greater awareness and concern for the link between tree-clearing and risk of salinity, due to the widespread development of dryland salinity in southern Australia following clearing. However, salinity problems are not new – historical evidence suggests that the breakdown of civilisations in Mesopotamia thousands of years ago was associated with soil salinity.

Water is the medium for movement of salt in the environment. In a landscape, water moves from recharge areas (areas where water enters the ground water) via transmission zones to discharge areas (areas where water leaves the ground water). As shown in Figure 10, recharge areas are usually on upper slopes and ridge crests. Transmission areas are located on the mid-slopes, and discharge occurs where some restriction to water flow causes the water to move towards the soil surface.

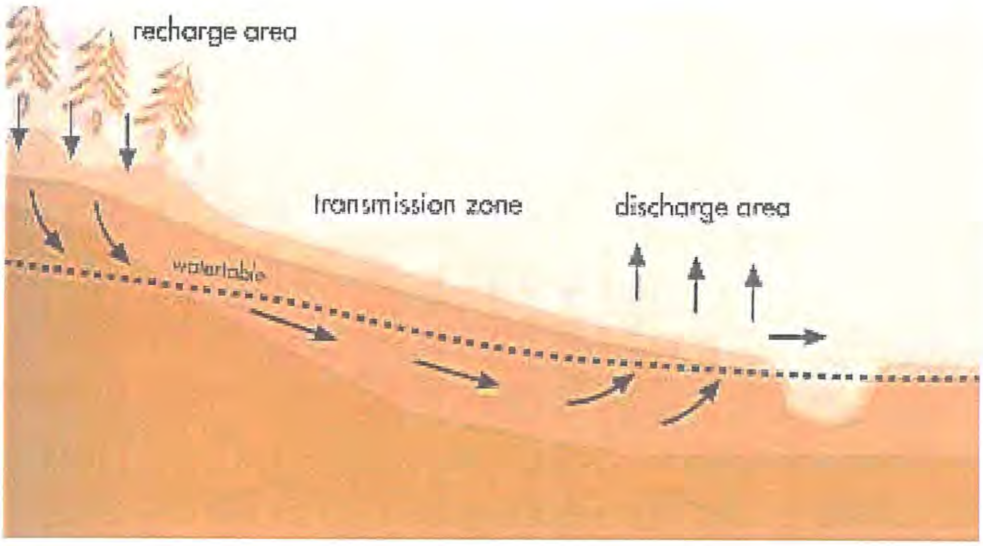



**Figure 10. A simple model of water movement in a landscape**

In undisturbed woodlands, a balance or equilibrium is established between input of water from rainfall, flows through the ground-water, and losses at discharge areas (see Fig. 11a). Trees play a crucial role as they are generally deeper rooted than herbaceous species and can withdraw water from deeper in the soil. Studies in several regions of Queensland have shown water use under cleared native pasture to be less than under uncleared woodland. Where trees are removed, therefore, any water that penetrates below the root zone of the herbaceous species cannot be removed by transpiration and will therefore add to the ground-water. It is this increase in ground-water recharge that can lead eventually to salt problems.

The water table will begin to rise and may continue to do so for many years and, if it reaches the surface, seepage areas or springs develop (see Fig. 11b). Where there is salt in the subsoil, there will be upward movement of salt that can be concentrated in the surface soil as the water evaporates. Salt from the discharge areas will also moves into streams and rivers causing downstream problems with water quality.

While there have been only small areas affected by salinity in Queensland, many regions have a significant risk of salinity developing; salinity outbreaks can take 50 years or more to develop following clearing.

Consideration of possible salt problems needs to be made in any decision on tree clearing. Identifying recharge areas, discharge areas and sources of salt are important in preventing and managing salinity risk. Maintaining or establishing trees, which can use water from deep in the soil, is critical in managing ground water and salinity, both to reduce recharge and to increase water use in discharge areas.

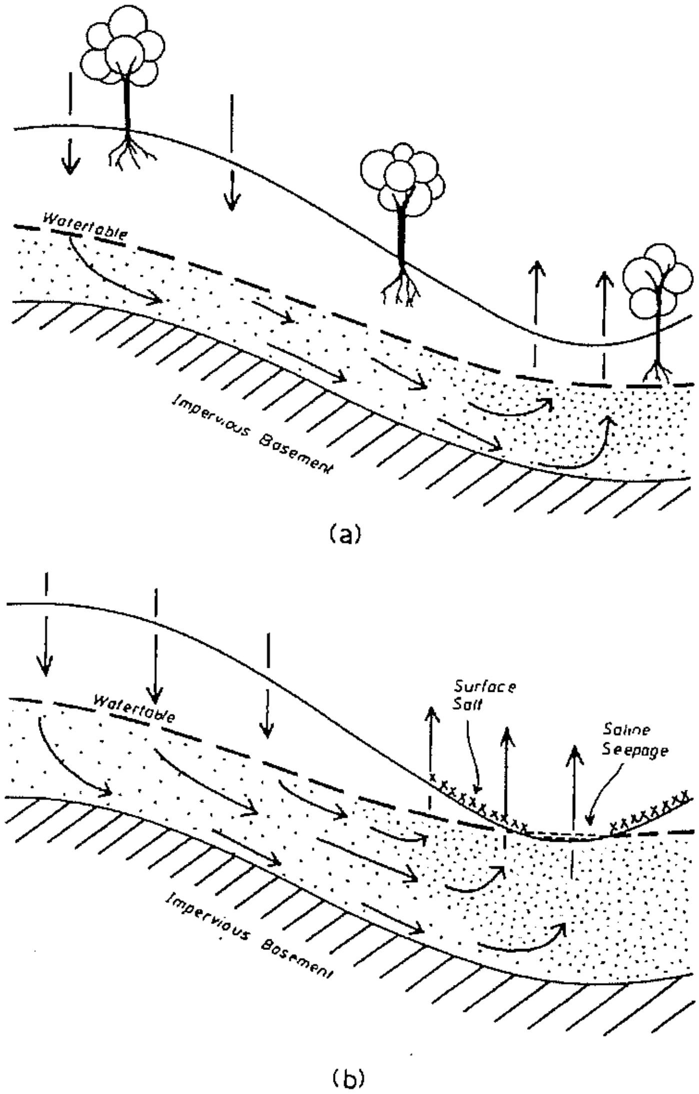



**Figure 11. Water table changes and secondary salinisation following tree clearing. a) before clearing the water table is well below the surface, b) after tree clearing it rises to near or above the surface.**

**Conservation of native plants and animals.** Although shrubs and tussock grasses are also important elements of wildlife habitat, trees are critical for many species. Live trees provide food, shelter and breeding sites for a range of species (birds, mammals, reptiles, invertebrates) while dead trees and fallen timber are important sites for shelter and breeding. Large mature trees with hollows are critical for some birds and mammals. Different vegetation types provide different types of habitat, and some species may depend on 1 or 2 particular land types. Therefore, significant areas representing the variety present on a property should be conserved to provide habitat for all species.

The riparian zones near water are a key component of wildlife habitat. They provide a rich and diverse habitat, and in addition act as refuges, ie, they provide resources (eg, food, nesting sites) which may be necessary for fauna to complete their normal life cycle, or which may be critical for survival in times of drought.

A major impact of clearing on wildlife is the fragmentation of their habitat with isolation of populations and deleterious genetic and ecological effects.

The woodland management strategy should therefore cater for conservation of significant areas of the habitats available. In areas with a history of extensive clearing, it is essential to maintain or encourage significant clumps of the woodland. In woodlands of southern Queensland, for example, it is recommended that clumps be at least 10 ha in size to be sustainable.

#### *6.2.4 Broader environmental issues*

**Greenhouse issues and carbon sinks.** In an undisturbed woodland, uptake of carbon dioxide ($CO_2$) by photosynthesis and loss by respiration and decay are balanced with little net change in the amount of carbon stored in the ecosystem. The woodland ecosystem therefore 'stores' carbon (in woody growth, plant roots and soil), with the amount stored dependent on the productivity of the site. For example, it has been estimated that woodlands in Queensland fix or store more than 100 million tonnes of $CO_2$ per year. However, clearing of trees results in the conversion of stored carbon to $CO_2$.

There are growing national and international concerns about the continuing rise in atmospheric $CO_2$ (mainly from industrial sources and land clearing) and the implications for the greenhouse effect and global climate change. The effect of woodland management on the carbon cycle is part of these concerns. Estimates of the contribution of land clearing, and other sources, to $CO_2$ emissions have been made, eg, in 1997 about 13% of the Australian emissions of $CO_2$ were associated with land clearing.

The international concerns about climate change have led to the development of a protocol to reduce greenhouse emissions and, if this is enforced, Australia will be required to limit growth in greenhouse gas emissions. This is another reason why there is increasing debate over woodland clearing.

### 6.3 How can I develop a woodland management plan?

Where fire is the primary tool being used, the woodland management strategy is part of the strategy developed for using fire. The strategy must specify the frequency, intensity and timing of fire, and must ensure that the grazing management strategy is consistent with this fire regime.

Where clearing or thinning of trees is being considered, a detailed mapping procedure should be undertaken (and is a requirement of most regulatory systems). This should build on the land type mapping done as part of the grazing management strategy. This will help plan:

- priority areas for clearing, based on carrying capacity response, susceptibility to regrowth, risk of salinity problems, and compliance with regulatory requirements.
- areas to conserve for habitat and/or for control of recharge and discharge rates

Other critical parts of the plan are:

- deciding on the most appropriate method and pattern of clearing for each type of country.
- on-going management needs, including grazing and fire management.

### *6.3.1 Identifying areas suitable for clearing*

The land type map used to develop the grazing management strategy provides both the mix of land types in each paddock and the current carrying capacity. This should be used to assess the paddocks that will provide the biggest responses to tree clearing in terms of carrying capacity. Also, consider the likely problems with regrowth on each land type and the role of different parts of the paddock in the controlling the recharge and discharge of under-ground water.

The map should delineate all areas on the property which should never be cleared. These include:

- areas that are unlikely to be approved for clearing because of conservation status or other government regulations;
- areas too steep (>10% slope);
- areas within 100 m of the banks of recognised watercourses;
- areas subjected to unacceptable erosion hazard;
- areas which would be exposed to increased risk of salting;
- additional areas voluntarily retained to conserve native plants and animals;
- areas of valuable timber for milling or fencing.

The remaining areas should be prioritised in terms of likely financial return and ease of on-going management needs.

Regulatory requirements usually require a map of land types to identify areas of vegetation types that should be fully or partially conserved. In Queensland, this assessment is based on mapping of 'regional ecosystems'. These broadly relate to land type mapping, and local government staff can help modify the map as appropriate. A regional ecosystem is a vegetation community within a bioregion that is consistently associated with a particular combination of geology, landform and soil. The conservation status of the individual regional ecosystems have been assessed as *endangered* (<10% of pre-European extent remains uncleared), *of concern* (10-30% of pre-European extent remains uncleared) and *no concern at present* (>30% of pre-European extent remains in an intact condition). This information is used to help process a tree-clearing application.

### *6.3.2 Choosing the appropriate method of clearing or thinning trees*
Trees can be cleared mechanically or with chemicals.

**Mechanical clearing.** For dense stands of trees (eg. gidgee, brigalow), mechanical clearing is the only economical method, but mechanical methods are also commonly used on eucalypt woodlands. Clearing large areas of forest and woodland is often done using a chain or cable pulled between two tractors. Pulling when the soil is moist is recommended, as a high proportion of the trees will be completely uprooted, reducing potential for regrowth. However eucalypts can be difficult to uproot completely and some snap off at or near ground level. Many of these broken off stumps, lignotubers and roots can produce regrowth. There can also be a high population of seedlings and small saplings not affected by the pulling operation. As a result, regrowth problems commonly follow pulling of timber. Dense regrowth of wattles is a problem on some land types, particularly the more infertile ones.

**Chemical clearing.** Two chemical methods are used for clearing – stem injection of herbicide and application of soil-absorbed herbicides to the soil. Chemicals used must be registered for use on the target species and for the method of application. Stem injection involves making a cut through the bark into the sapwood and injecting a small quantity of the appropriate herbicide (eg, Tordon). This method allows selective treatment, and therefore selective retention, of trees. Mortality of treated trees is generally high but seedlings are not treated and will be a source of regrowth. Chemicals suitable for soil application (eg. Graslan) can be applied from the air and will kill both adult and juvenile plants of susceptible species.

### *6.3.3 Choosing the appropriate pattern of clearing or thinning*
In the past, areas treated by stem injection have left selected trees or very small clumps in park-like fashion through the paddock. Mechanical clearing has tended to leave a few clumps of trees, often quite small in area.

The following recommendations on clearing patterns are based on achieving a balance between maximising forage response, reducing regrowth potential and retaining significant areas of trees. The recommendations are:

- retain 20% of the original tree population on this land in wide strips (minimum 100 m) which will provide shade and shelter for stock, provide habitat and movement corridors for native fauna, act as a fire and wind break and a future timber source if required.
- where trees are retained in clumps, rather than in strips, make the clumps at least 5 ha in area (shade clumps which are too large can hinder mustering, it they are too small they are not sustainable). If necessary at a later stage, some of these areas can be fenced to encourage regeneration.
- interconnect the timbered strips to water courses, retained woodland areas and shade lines throughout the property and, wherever possible, place them contiguous with similar strips on neighbouring holdings; this is best achieved with the aid of aerial photographs and the detailed property map.

It is not advisable to leave scattered trees over the paddock as a means of achieving the 20% retention. This pattern leads to fragmentation of wildlife habitat and contributes to continual management problems with seedling regrowth.

### *6.3.4 On-going management needs*

On-going management should be based on a grazing and fire strategy that:

- adjusts stocking rate to take advantage of the increased forage production
- provides for regular wet season spelling
- provides for regular use of fire

In some cases, eg, pulling of eucalypt country, the amount of regrowth likely to occur may not be effectively contained by fire alone. Follow-up chemical or mechanical control may be required. This should be both planned for and costed into the financial assessment.

## 6.4 How do I assess the financial implications of woodland management?

In evaluating the financial implications of the woodland management plan a number of factors need to be considered these should include:

- costs of the initial treatment, where some form of tree-clearing or thinning is used; this may also apply to use of fire if reduced stocking has been required to provide adequate fuel;
- costs of on-going management: follow-up burns; mechanical or chemical control of regrowth;
- likely pasture response and benefits for carrying capacity and animal production, and
- costs associated with not changing the managements strategy, eg, continued woodland thickening and reduction in carrying capacity.

Other factors such as the value of trees for timber and value of retaining shade and shelter may also be important.

The example summarised in Table 1 looks at a comparison of the financial implications of different management strategies for poplar box woodland in central Queensland. The analysis is based on:

- 1000 ha of land
- pasture production determined by land types and tree basal area
- carrying capacity based on a safe utilisation rate of 30%
- steers entering the paddock at 180 kg and being sold at 450 kg
- income of $1.00/kg live-weight gain
- average rainfall.

The Net Present Value (NPV) is based on a 15-year time frame and a 6% discount rate.

**Table 1. Economic analysis of some tree clearing strategies for a poplar box woodland in central Queensland. Note that Net Present Value = NPV and Internal Rate of Return = IRR.**

| Treatment | NPV ($) (relative to control) | IRR (%) |
| --- | --- | --- |
| Control (trees untouched) | | |
| Stem inject all trees | 51,500 | 24 |
| Scattered (retain 20% trees, stem inject the rest) | -21,000 | |
| Graslan 5 kg/ha (100% area) | 79,500 | 28 |
| Pull and burn 100% area | 59,000 | 22 |
| Strips (retain 20% trees) - pull and burn | 47,000 | 22 |
| Strips (retain 20% trees) - Graslan 5 kg/ha | 63,650 | 28 |

This analysis shows that:

- retaining trees scattered across the landscape is a very unattractive option from an economic viewpoint;
- maximum dollar return may come from clearing the whole area, but this strategy is unlikely to be desired by the landholder or permitted by regulation
- the returns from retaining 20% of the area as trees provides comparable returns to clearing the whole area;
- chemical treatment is superior in this example; however, this may not always be the case.

The above analysis considers only some of the costs and benefits to the land owner. Additional on-farm considerations include:

- risks of salinity
- aesthetic value of tree cover
- shade and soil-conditioning value of tree cover
- producers' interest in conserving woodland.

Off-farm considerations are even more difficult to evaluate in an economic analysis but include both potential costs from clearing (eg. off-property salinity, increase in greenhouse gas emissions, biodiversity loss, aesthetic values) and potential benefits (e.g. increased profitability of rural communities).

# 7. MANAGING WEEDS

## 7.1 Why is weed management important?

Weeds are a common problem in most agricultural activities and grazing lands are no exception. The most common concern with weeds is when they invade pasture, competing for water and nutrients and reducing pasture growth. However, weeds may also affect grazing land management by:

- being a physical barrier to movement and visibility, thereby reducing animal access to water or forage, and making mustering more difficult
- being poisonous or tainting produce
- affecting the operation of machinery
- causing physical injury (e.g. spines);
- harbouring feral animals, eg, feral pigs
- affecting human health;
- being hosts for diseases or insects;

Weeds can be both a cause of poor land condition, by reducing the amount of useful vegetation, and a symptom of poor land condition, as they can fill gaps in the pasture created by poor management.

Managing weeds affects a major gateway to sustainable production from grazing lands: rainfall use efficiency. The prevention and control of weeds improves RUE through reducing competition from undesirable plants, thereby encouraging growth of desirable pasture species.

Managing weeds can also benefit diet quality, by reducing incidence of toxic plants.

Whether a plant is considered a weed, and how seriously it is viewed, depends on individual perspectives. On grazing lands, there is usually consensus about what is a weed, but this perspective can change for other land uses. For example, introduced pasture species are weeds from the perspective of managing conservation areas. Weediness therefore depends not only on the characteristics of the plant but also on where it is growing and on the uses made of the land.

Some native species are perceived as weeds in particular situations. Native woody weeds are prominent in south west Queensland, northern New South Wales and central Australia. Dense regrowth of native trees and shrubs may also be a cause for concern e.g. eucalyptus, cypress pine, gidgee and mulga. These situations are dealt with in woodland management. In weed management we will deal with non-native weeds.

Weed management requires:

- an awareness of existing and potential weed species and their potential impacts ; and
- an understanding of the ecology of weeds, ie, how they invade and spread.

### *7.1.1 Weeds of importance to grazing lands*

All States and Territories have legislation regarding noxious or declared weeds and the obligations for landholders to control them.

A national assessment of Australian weeds has been made as part of the National Weed Strategy. Seventy-one weeds nominated by all states and territories were assessed for invasiveness, impacts, potential for spread, and socioeconomic and environmental values to determine "Weeds of National Significance" (WONS). These 'top 20' weeds are shown in Table 1. It is important to note that the potential for further spread (and thus to cause increased losses) is one of the criteria for both WONS and declared weeds.

Each region will have important weeds that are not in this list of 'top 20' weeds. For example *Mimosa pigra* is a major problem in the Top End of the Northern Territory and is not on the top 20 list.

**Table 1. Inaugural list of Weeds of National Significance.**

| Rank | Common name | Scientific name |
|---|---|---|
| 1 | Parkinsonia | *Parkinsonia aculeata* |
| 2 | Mesquite | *Prosopis* spp. |
| 3 | Blackberry | *Rubus fruticosus* agg. |
| 4 | Lantana | *Lantana camara* |
| 5 | Rubber vine | *Cryptostegia grandiflora* |
| 6 | Bitou bush/boneseed | *Chrysanthemoides monilifera* |
| 7 | Prickly acacia | *Acacia nilotica ssp. indica* |
| 8 | Hymenachne | *Hymenachne amplexicaulis* |
| 9 | Salvinia | *Salvinia molesta* |
| 10 | Mimosa | *Mimosa pigra* |
| 11 | Cabomba | *Cabomba caroliniana* |
| 12 | Chilean needle grass | *Nassella neesiana* |
| 13 | Athel pine | *Tamarix aphylla* |
| 14 | Willows except weeping willows, pussy willow and sterile pussy willow | *Salix* spp. except *S. babylonica, S. X calodendron* and *S. X reichardtiji* |
| 15 | Serrated tussock | *Nassella trichotoma* |
| 16 | Parthenium weed | *Parthenium hysterophorus* |
| 17 | Pond apple | *Annona glabra* |
| 18 | Gorse | *Ulex europaeus* |
| 19 | Bridal creeper | *Asparagus asparagoides* |
| 20 | Alligator weed | *Alternanthera philoxeroides* |

### *7.1.2 Environmental weeds*

Environmental weeds are species that invade native plant communities and cause changes to the vegetation structure, and/or the function of ecosystems. This may result in changes to the faunal habitat as well as to changes in the vegetation. Specific concerns have been expressed about:

- changes to habitats for both plants and animals leading to a loss of biodiversity as native species decline or are displaced;
- restricting access for animals and humans, eg. spiny shrubs and dense stands of vines;
- altered fire regimes, usually towards more frequent and/or intense fires;
- changed drainage patterns and flow rates; and
- altered landscape appearance with a decline in aesthetic values.

### *7.1.3 Ecology of weeds: how they invade and spread*

Understanding how weeds invade and spread requires knowledge about:

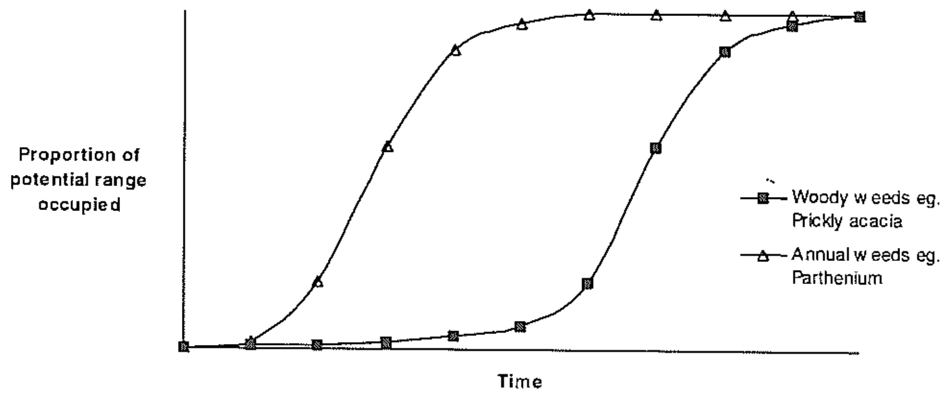
- phases of weed increase
- how weeds grow and reproduce
- how disturbance might create favourable environments for weeds
- preferred habitats

**Phases of weed increase.** The pattern of increase in a weed population generally involves the following phases (see Figure 1):

(a) introduction to the area;
(b) a latent or lag phase when the weed increases only slowly;
(c) a period of rapid and obvious increase (expansion phase); and
(d) a final phase when the weed remains a large problem or control measures reduce the population.

The duration of the lag and expansion phases is species specific and influenced by environmental conditions.

**Figure 1. Generalised representation of the typical spread of annual and woody weeds over time.**



Introduction to an area is sometimes accidental, but many serious weeds in grazing lands were deliberately introduced to the area as ornamentals or for some other purpose. Animals, machinery, and purchased seed and fodder are possible sources of weed seed.

Following introduction, a weed usually becomes naturalised at low density or within small areas. It may be present in an area for an extended period, perhaps several decades, before becoming widely noticed or causing serious loss of production. Different species have different lag times, as may different outbreaks of the same species. The lag phase can last a long time, eg, rubber vine, prickly acacia and chinee apple were all introduced over 100 years ago.

At some point, the weed begins a period of rapid expansion, both in terms of total population size and the number and size of individual infestations. Many weeds, unfortunately, reach this stage before they are recognised as being serious weeds. Effective control at this stage is expensive and difficult.

Eventually, the weed will reach a stage at which it presents major problems across much of its potential range because of the large population that is present.

The rate at which a weeds species will go through these phases depends on many factors including:

- the scale of initial introduction;
- the number of sites at which introduction occurred;
- the distribution of sites at which introduction occurred;
- the amount of suitable habitat;
- the plant's natural dispersal (seed spreading) mechanisms and the extent to which natural dispersal is assisted by human activities in the area;
- the suitability of the climate.

As you would expect, species that are introduced on a large scale and/or introduced to a large number of sites that are in close proximity to suitable habitat, will colonise relatively quickly.

Most weeds spread by natural means (wind, water), via animals and birds, or by human activities.Humans unintentionally spread weed seeds in a number of ways – by sowing contaminated seed, using feedstuffs containing weed seeds, on vehicles and machinery, through movement of stock from other properties or regions, and on their clothing. *Limiting the spread of weeds is critical* and should be part of general property management. Some examples of good property hygiene are:

- thoroughly cleaning machinery that has been used in weed infested areas;
- avoiding purchase or transfer of agisted stock from weed-infested areas to clean areas;
- quarantining animals moving from known weed-infested paddocks before moving them to clean paddocks, especially with weeds like Giants Rats Tail grass; and

- regularly monitoring entrance roads, around homesteads and buildings, water points, stock yards and other frequently visited areas.

**How weeds grow and reproduce.** For a plant to become a weed, it must be able to complete its life cycle and spread in its new range. Knowing the life cycle of a weed (Figure 2) can help identify the key times or periods for most effective prevention and control.

Herbaceous weeds can be either annuals (i.e. species which complete their life cycle in less than a year) or perennials (i.e. plants which live for two years or longer).
Annual species depend on seed for their long-term persistence. At least some of their seed will be dormant and may remain so for some time, and annuals often have large persistent banks of seed in the soil.

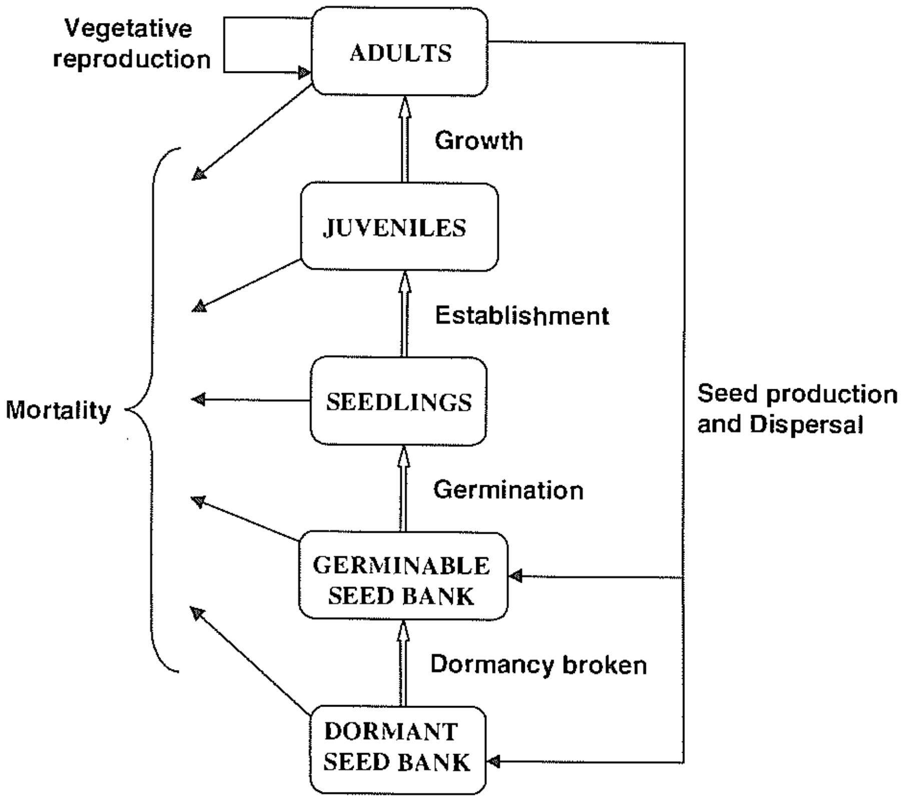



**Figure 2. Generalised life cycle of a weed species**

In contrast to annuals, perennial plants can survive for several years or even decades, depending on species. Perennial species may set seed each year, but are not dependent on annual production of seed for persistence. In addition to seeds, perennial weeds often reproduce vegetatively eg, via stolons or runners, rhizomes, suckers, tubers, corms, bulbs or root divisions.

A number of important weeds in northern Australia are long-lived woody perennials. Once seeds of these species spread, they can germinate at any time that moisture supply is sufficient, but woody weed seedlings often do not survive their first dry season. Given the need for suitable conditions for both germination and seedling survival, successful survival of woody weeds to adulthood may occur irregularly, but with large population increases in wet years. Woody plants may take several years to reach a size at which they are capable of producing seeds but, over their life span, they can produce many thousands of seeds. Some (e.g. mesquite, prickly acacia and chinee apple) form persistent soil seed-banks which may last for several years, while seeds of others (e.g. rubber vine) either germinate or decay within a year. Many woody weeds (e.g. parkinsonia, mesquite, prickly acacia, chinee apple, lantana, and yellow oleander) resprout following damage to, or removal of, the above-ground parts of the plant.

The differences between annuals and perennials in relying on seeds or underground parts for long-term persistence has important implications for weed control. For annual weeds, we aim to prevent seed production and deplete the soil seed reserves while, for most perennial weeds, the underground vegetative organs must also be destroyed.

Other variations in plant life cycle can also be important for effective weed control. For example, the longer a plant takes to reach reproductive age, the longer the period for achieving control before new seeds are added to the system. Also, the longer seed remains viable in the soil, the longer the period before an infestation can be considered to be under control.

**Disturbance-creating the environment suitable for weeds.** Disturbance is a term to describe the suppression, destruction or removal of vegetation from an area. By removing vegetation, disturbance creates gaps and the opportunity for a weed to establish.

Weeds are more likely to establish and spread where grazing management, woodland management or some other factor has caused a decline in land condition, thereby creating extra gaps in the pasture. While some weeds will invade an area regardless of land condition, the rate of build-up and spread of most species is enhanced where land is in poor condition.

Grazing and fire management can greatly affect the spread and build-up of weeds. For example, parthenium explodes in over-grazed situations, while many woody weeds are favoured by inadequate use of fire.

**Dispersal and preferred habitats.** The term dispersal refers to the means whereby seed or other propagules spread from the plants that produced them. Weeds employ a wide variety of dispersal mechanisms. Most seeds are dispersed either by wind, water or animals, though there are many variations on these basic mechanisms (Table 2). Some species have in-built mechanisms for catapulting their seeds away from the parent plant. Even in species that have special adaptations for dispersal, many seeds may fall directly to the ground and may remain close to the parent plant. Human activity and cattle movement contribute substantially to the dispersal of weeds.

**Potential for long distance dispersal of chinee apple during cattle transport**

Large numbers of viable seeds of chinee apple are voided in the dung of cattle that have been feeding on chinee apple fruits. A sample of 58 dung pats yielded an average of 16 viable seeds per dung pat. Assuming that each beast produces 10 such dung pats before it has voided all seeds, a road train transporting 80 cattle would be transporting 16 x 10 x 80 = 12,800 viable seeds. This could initiate an infestation.

Weeds are usually unevenly spread across an area. Like other plants, weeds have their particular needs and therefore will be better adapted to some parts of the landscape compared to others (Table 3.). Competition from existing plants and the amount and type of disturbance also vary and interact with the habitat preferences of the weed to determine both the location of infestation and the rate of spread.

**Table 2. Examples of how different weeds are dispersed.**

| | |
|---|---|
| **Wind-dispersed** | Rubber vine; Buffel grass |
| **Water-dispersed** | Parkinsonia; Hymenachne; Giant rat's tail grass |
| **Explosion of fruits** | Castor oil plant |
| **Dispersed following ingestion by animals** | Prickly acacia; Chinee apple; Mesquite (*Prosopis* spp.); Harrisia cactus; Sicklepod; Lantana |
| **Dispersal by attachment to animals** | Khaki weed; Spiny head sida; Noogoora burr; Giant rat's tail grass |
| **On motor vehicles and farm machinery** | Giant rat's tail grass, parthenium |

Riparian zones are especially susceptible to colonisation by weeds, as water and nutrients are in greater supply in these areas. Species that develop particularly serious infestations in riparian zones are rubber vine, castor oil plant, Guinea grass, parkinsonia and chinee apple. All occur in other parts of the landscape but plants are larger, grow more densely and produce more seeds in riparian zones. In lower rainfall zones, particular weeds will tend to be more dependent on riparian zones or other relatively fertile parts of the landscape.

**Table 3. Habitat preferences of some important weeds in the Burdekin grazing lands**

| Species | Habitat preferences |
|---|---|
| Castor oil plant | Common along water courses and disturbed areas |
| Chinee apple | In areas with an average annual rainfall of 470-1200mm; on wide variety of soil types including coarse-textured gravelly soil, deep alluvials, sobdic and cracking clay soils; often in areas that have been severely disturbed, especially where native trees have been cleared |
| Lantana | Wide variety of habitats ranging from dry hillsides to shaded gullies; range of soil types but does best on more fertile soils; |
| Parkinsonia | Variety of soil types but commonly on areas of heavy soils that are periodically flooded |
| Parthenium | Heavily grazed areas with average annual rainfall of 400-800mm; particularly common on alkaline clay loam soils |
| Rubber vine | Most common in the wet-dry tropics where average annual rainfall 400-1400mm; especially prevalent in riparian areas including along major rivers and minor creeks |
| Giant rat's tail grass | Occurs on wide range of soils; most likely to occur where average annual rainfall is above 700mm |
| Harrisia cactus | Most common in brigalow soils and softwood scrubs; shade tolerant |
| Bellyache bush | Most frequent in riparian habitats and on more fertile soils |

## 7.2 How can weed management improve land condition?

Management of weeds improves land condition by reducing their competitive effect on desirable pasture species. Herbaceous weeds like parthenium progressively displace the pasture, reducing carrying capacity and animal performance. Woody weeds compete with pasture in much the same way that native woody plants do, reducing pasture production with increasing density.

Any reduction in the density or vigour of weeds will therefore improve pasture production and carrying capacity. However, weed management is often not considered a priority until the weed is making an obvious impact on pasture production. Low densities of weeds have only a comparatively small effect on pasture growth, and there is often reluctance to spend resources on controlling weeds at this stage. Ironically, this approach inevitably results in very heavy expenditure at a later date, as weeds are more difficult and expensive to control at high densities. *Preventing weed problems is the key to cost-effective improvement of land condition.*

## 7.3 What is the best way to manage weeds?

Weed management should be based on a strategy that has realistic objectives. Usually only limited resources are available for weed management and it is important to get maximum benefit from them.

Eradication is rarely a realistic objective. In most cases, eradication is possible only when a concerted effort is made with large resources early in the invasion process when the infestation is very restricted.

### *7.3.1 Principles of weed management*

There are several important principles that provide a basis for managing weeds:

- **Be aware** of all existing and potential weed species
- **Prevent** the introduction of new weeds and the spread of those already present.
- **Detect** weed infestations early
- **Intervene early** in the process of weed invasion and spread.
- **Integrate** a variety of management techniques.
- **Act** strategically against weed infestations.

**Be aware of existing and potential weed species.** Communication with neighbours and with land management staff in both local and state governments is important for awareness. Plant identification books and farm-notes are available to help improve awareness and ability to identify potential weed species. An unknown or unusual plant species should always be treated with suspicion.

**Prevent introduction of new weeds.** Property hygiene is critical. Cattle are agents of spread for a number of weeds (prickly acacia, mesquite, chinee apple, giant rats tail grass) and their movement should be controlled to prevent spread. Preventing introduction of weeds in hay, feed, machinery and vehicles is also important.

Limiting the opportunities for weeds to establish and spread by maintaining good condition grazing land is an essential part of any effective weed management plan.

**Detect weed infestations.** Effective management depends on reliable and efficient detection. Detection depends on the ability to recognise weeds and suspicious-looking plants. It is helped by knowledge of how the plant spreads, preferred habitats, and the types of disturbance that favour a particular weed. Ideally the whole property should be monitored but if this is not possible then resources can be concentrated on areas near houses and buildings, stock yards, water points, roads and in particular habitats.

**Intervene early.** Early intervention allows containment and possible eradication if sufficient resources (money, time, labour) are available.

**Integrate a variety of management techniques.** A suite of management techniques is available, including mechanical treatment, use of herbicides, burning, biological control, and use of particular herbivores (e.g. goats, camels). In general, no single method is sufficient for effective control at a reasonable cost. Rather, weed management is often more effective when a number of techniques are integrated together. For example, fire can be used to kill a large proportion of small rubber vine plants and reduce the size of large plants; mechanical or chemical methods can be used to control the remainder. Alternatively, mechanical or chemical methods can be used to reduce or remove large mature plants and subsequent fires used to prevent seedling establishment.

**Act strategically against weed infestations.** This emphasises developing a strategy for weed management, rather than just reacting to each weed problem. This requires analysis of:

- The priority of different weed infestations: rank these from high to low priority to determine where action is best taken;
- The mix of techniques to use;
- When and where to apply these techniques;

In all cases, early intervention is recommended. Where more than one property in an area is affected by a weed problem, greatest overall benefit may come from group action, eg, concentrating on those infestations that pose the greatest threats to the district or catchment.

### *7.3.2 Weed control methods*

There are four general types of control methods that can be used to reduce weed infestations: physical control, application of herbicides, burning and biological control. Each has advantages and disadvantages relating to effectiveness and efficiency. Methods should be selected and applied on the basis of both how well they control weeds and how well they encourage the growth of desirable pasture species.

**Physical control** includes both manual (hand pulling, cutting, digging) and mechanical control measures (chain-pulling, blades, stick rakes, bladeploughs, slashers, discs and ploughs). Physical control can be effective for many perennial weeds, especially woody species, but many species will resprout following treatment. Most mechanical methods cause soil disturbance, opening up the prospect that germination and establishment of the same or different weeds will be encouraged.

**Herbicides** are available for most weed species. Although effective when used correctly, chemical weed control can be expensive when a large area of land with low productivity is involved. Where it is necessary to treat individual plants, chemical application can be time-consuming and the effectiveness will depend on the ability to locate all plants.

**Burning** is a useful control and containment method. However, the effectiveness of fire varies with weed species, plant age, weed density, slope, and fire intensity. Woody weeds are most affected by fire when they are young and small. Some species are resilient even in the face of frequent burning e.g. chinee apple. It may be necessary to destock an area targeted for burning in order to achieve sufficient fuel. Post-fire destocking is also highly desirable to allow the pasture to recover.

**Biological control** involves finding and releasing predators or pathogens that are specific to particular weeds. Biological control programs usually only commence when other forms of weed control are either too costly or ineffective. Development of biological control is expensive, time-consuming and risky. Although there have been some very notable successes with biological control in Australia, such as the use of the Cactoblastis moth to control prickly pear, results are often less successful. Thus, biological control will often need to be used with other techniques.

Goats, and more recently camels, are sometimes promoted as weed control agents. Results are usually variable.

### *7.3.3 The need for follow-up management*

Weed management is both ongoing and long-term. In any program it is important to be able to control any weed regrowth that occurs – often the first treatment will not be 100% successful and some plants will survive or new seeds will establish. Regular monitoring and treatment of these areas is necessary to ensure that the benefits from the initial treatment are not lost.

### *7.3.4 Risks associated with weed control*

Risks associated with weed management include:

- Poor kill of weeds
- Creation of gaps for other weeds
- Safety and health factors
- Effect on non-target plants
- Residues in animals
- Herbicide resistance

**Poor kill.** Weeds are well adapted species so there is always a risk treatment will not be successful and money and resources used will be wasted. Where treatment is ineffective and a poor kill results, the gaps created by the treatment may be refilled by the same weed (from surviving plants or seeds) or invaded by other weed species.

**Creation of gaps for other weeds.** Ironically, successful weed control will leave gaps that can be exploited by other plants. It is essential that management post-treatment favour desirable pasture plants and limit further weed invasion.

**Safety and health factors.** Many weed control methods have inherent risks e.g. the use of large machinery to clear infestations of woody weeds, the application of toxic chemicals. Proper training of operators is essential.

**Effect on non-target plants.** While the careful application of herbicides can eliminate weeds with little or no damage to other plants, there remains the possibility that non-target plants will be affected if the herbicide drifts in windy conditions or moves in water to other locations.

**Residues in animals.** Residues in animal tissues are a major concern with the use of pesticides. It is essential to check on potential residue problems: check the label and seek advice if in doubt.

**Development of herbicide resistance.** Development of herbicide resistance in weeds has become an important issue in the past decade. The problem has developed with annual weeds in temperate areas, where the use of herbicides has been greater and more frequent than in the grazing lands of the tropics and sub-tropics. In the tropics and subtropics, there are currently no reported cases of weeds developing resistance to herbicides.

## 7.4 How do I develop a weed management plan

A successful plan for weed control cannot be developed in isolation. It must be integrated into the overall management plan of the property.

### *7.4.1 The seven-step approach*

There are seven steps to developing your weed management plan. Each of these steps is explained in more detail below.

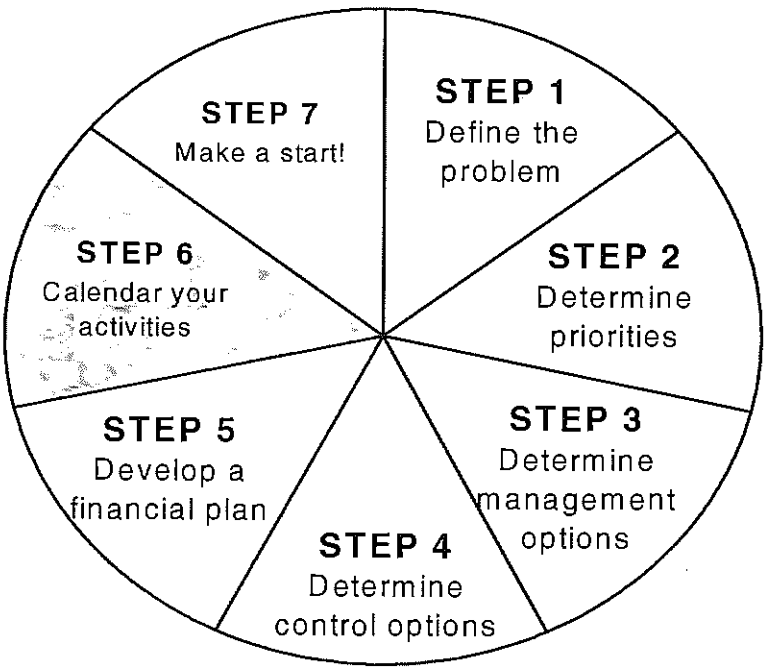



**Figure 3. The seven-step approach to developing a weed management plan.**

**Step 1: Define the Problem**

- Draw a property map including property and paddock boundaries, water points and creeks/rivers.
- Identify and indicate land classes (different types of country).
- Indicate areas of weeds, noting the size, density and species of each infestation.

An appropriate base map from which to commence a plan may be an aerial photographic mosaic, satellite image or even a hand sketch. However, the greater the accuracy of your map, the greater its usefulness in estimating costs of control. The map used to develop the grazing management strategy will suit this purpose. Use separate overlays (plastic transparency) for each of the components of your plan.

**Step 2: Determine Priorities**

- Determine priorities for control on both a paddock and property basis.

When determining priorities it is important to consider:

- Where are weeds adversely affecting management of the property e.g. around water points, yards and mustering corridors.
- What areas are being most affected in terms of reduced carrying capacity
- Where are the high seed-source areas.
- Control efficiency (the treatment of the maximum area for the minimum cost).
- Risk assessment (which areas are at risk of imminent invasion and spread).
- Which areas/paddocks/land classes are the most productive.
- What legal or neighbourly responsibilities you have.

**Step 3: Determine Management Options**

- Identify management strategies that will reduce or prevent the spread of the weed.

Management strategies may reduce future costs of weed control. For more information about the strategies available it is recommended that you seek the advice of a Land Protection officer or weed specialist from the appropriate State or Territory Department.

**Step 4: Determine Control Options**

- Identify resources currently available or affordable e.g. labour, machinery, spray equipment, etc.
- Determine the control methods required to address all three phases of the control program: initial treatment, follow-up and on-going monitoring.

There is now a comprehensive range of control methods available for weed control. These include various herbicide application techniques, mechanical control, land management options (i.e. fencing and stock management), fire and biological control.

Usually an integrated approach using a combination of techniques will be required.

**Step 5: Develop a Financial Plan**

- Estimate costs of control for each of the priorities identified.
- Assess the costs of control against other operations on the property.
- Identify the availability of financial incentives including tax concessions, low interest loans or labour programs.
- Integrate control costs into the short-term and long-term property budgets.

It is necessary to consider control costs in conjunction with the evaluation of priorities and control options. It is recommended that you seed the advice of a Land Protection Officer or Weed Specialist, or conduct small scale trials, before committing a large amount of funds.

**Step 6: Calendar Your Activities For Weed Control**

- Consider the effectiveness of control methods in different seasons and balance with time available for control.
- Timetable weed control activity.

Weed control should become an annual part of property management. Consideration should also be given to the level of follow-up control required. It is risky to treat an area larger than that which you can attend to for follow-up within the year or two following treatment.

**Step 7: Make a Start!**

- Commence the implementation of your plan.

A plan is useless without implementation. There are a host of reasons why weed control is not commenced but rarely does the problem go away. Sometimes due to the enormity of the problem or a lack or experience, it is difficult to undertake the planning process; in these situations it is advisable to gain professional advice and/or start at a smaller scale.

### *7.4.2 Points to remember*

Weed control usually has no "quick fix" solution. Therefore, the development of a weed control plan and a commitment to that plan is essential for the long-term effectiveness of your efforts.

While your plan needs to be structured, it must also be flexible enough to handle changes brought about by external, uncontrollable influences such as drought and commodity price fluctuations. It is also critical to evaluate your plan annually to assess the effectiveness and efficiency of the control options and strategies implemented.

The cost of not managing weeds now may be exorbitant in terms of future costs and lost production.

## 7.5 How do I assess the financial implications of weed management?

The likely financial returns from a weed management program can be estimated by comparing the costs (both the initial and ongoing) and expected returns. Since weed management programs are generally long-term the net cash flow can be calculated for each year and discount rates applied to convert the values to net present value (NPV).

Costs can generally be determined with some degree of certainty but quantifying benefits can be difficult. Labour, energy and machinery costs should be included when calculating costs, not just the obvious costs such as herbicides. Benefits are both direct (e.g. reducing animal poisoning or health problems, reducing contamination of animal products) and indirect. The indirect benefits are derived from changes to pasture quantity and quality and are the most difficult to quantify. Some estimate of the extra animal production resulting from the weed control needs to be made and included in the economic analysis.

A major problem in making an economic evaluation is deciding how big a problem the weed infestation may be in the future. This will determine how large the impact on production will be and thus how large the benefits will be from doing control now.