4. Pasture and Grazing Management

J. Scott, J. Pratley, J. Virgona
Ed. D. Cottle

Learning objectives
On completion of this topic you should be able to:

• outline the key principles behind pasture establishment and grazing management of pastures
• demonstrate a thorough understanding of grazing management concepts and the science behind grazing management principles
• evaluate the economics of weed control
• discuss relevant literature relating to grazing management and sustainability
• access and utilise recent research and extension efforts describing sustainable grazing systems and recognise the difference between anecdotal claims and objective evidence
• Understand some of the important differences in the capacity of different pasture species to support sustainable wool production and the important influences of fertiliser, stocking rate and grazing management

Key terms and concepts
Pasture establishment; Grazing management terminology (especially continuous, rotational and tactical grazing); Spatial and temporal changes in grazing behaviour and pasture supply; Sustainability; 3-leaf and 4-leaf stage of plant growth; Grazing tolerance; Light interception and pasture growth; Selective grazing; Stocking rate and its interactions with fertiliser and pasture utilisation; Herbage intake; PROGRAZE, herbage mass and digestibility; Rest period; Remote sensing of herbage; Nutrient responses; Animal production per head and per hectare

4.1 Introduction
A successful grazing enterprise provides high levels of animal performance but its ongoing success or sustainability depends also on the maintenance of high quality pasture. Emphasis therefore needs to be placed on ensuring good establishment of desired pasture species and ongoing management of the pasture to minimise deterioration of plant populations. The establishment process is very expensive and it is sound economics to maintain the pasture in a productive condition for as long as possible to spread the establishment costs over more years.

It follows that pasture species and varieties need to be well adapted to their environment. Local knowledge and research outcomes are vital sources of information as to what is best suited to a particular environment, soil type and proposed enterprise.

Pastures are by far the cheapest form of nutrition for grazing ruminants, as they can produce one tonne of feed for as little as $10 to $30 per tonne (dry matter) per year. When one contrasts this with prices for hay of $180 per tonne through to grain of up to $500 per tonne (and more during drought) it is easy to see the relative costs of pasture being much lower than purchasing grain for supplementary feeding for example. Even with irrigated pastures for dairy production, the cost per tonne of the grain may rise but rarely above $60 per tonne of dry matter produced. Of course, the nutritional value of 1 tonne of pasture is usually lower than that of grain but the difference may be only 30%, which is much less than the price differential.

There are greater public expectations of graziers than has been the case in earlier times. The ongoing pressure of raising productivity to maintain profitability is ever present, whilst at the same time the community expects the natural resource base to be protected from degradation and biodiversity to be enhanced (Kemp and Michalk, 2007). There are the environmental challenges of...
soil salinisation and acidification and the ever likely incidence of drought, all of which require management for sustainability (Chapter 19). Improvements in water use efficiency lead to productivity gains and also contribute to the amelioration of environmental degradation aspects, such as soil erosion and salinisation.

Further, the global influence of climate change adds an extra dimension whereby projected changes in local climate have to be addressed and attention given to greenhouse gas emissions (Keogh and Cottle 2009). Ruminants are the major source of these emissions in agriculture. Reducing time to market provides one way to limit such methane emissions and this requires a high quality feed supply.

These and other issues are canvassed in this chapter to identify the principles of importance in a successful sheep grazing enterprise.

**Zone pasture characteristics**

**High-rainfall zone**

This zone receives on average over 550 mm annual rainfall and is located in the most southern or eastern parts of Australia. In the south, rainfall incidence is winter-dominant, but in northern New South Wales and southern Queensland rainfall becomes more summer-dominant. In general terms, there are two major pasture types found in this zone. Firstly, sown pastures based on temperate (or C$_3$) exotic perennial grass species such as phalaris, tall fescue, cocksfoot and perennial ryegrass usually mixed with annual or perennial legumes (Table 4.1). Such pastures often do not persist due to a range of management and climatic factors. Hence, management for persistence has been a focus at both farm and research levels.

The second major pasture type is characterised by the presence of native grasses as the major perennial species. Depending on the extent to which native species dominate these pastures they may be referred to as ‘native’ (invaded by few if any exotic species) or ‘naturalised’ (dominated by exotic volunteer species with some native grass present). We use the term ‘native’ for convenience for any pasture where the dominant perennial species is a native grass. From a management perspective the important characteristic of these pastures is that they are unsown but are managed mainly with grazing and fertiliser. Such native pastures may contain a range of species depending on the extent to which they have been grazed since colonisation. These include summer-growing species such as *Themeda* (kangaroo grass), *Bothriochloa* (red grass), *Aristida* (wire grass) and *Chloris* (windmill grass) and cool-season grasses such as *Austrostipa* (spear grass) species, *Austrodanthonia* (wallaby grass), *Poa* (Poa tussock) and *Microlaena* (weeping grass) species. As a generalisation, except for relatively short periods in the early vegetative stage, the quality of forage from native grasses for sheep production is a limitation.

**Table 4.1.** Improved legumes and grasses for the high-rainfall sheep zone in Australia.

<table>
<thead>
<tr>
<th>Species</th>
<th>Minimum rainfall (mm)*</th>
<th>Some features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Perennial grasses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phalaris (<em>Phalaris aquatica</em>)</td>
<td>400 S, 700 N</td>
<td>Most persistent of the perennial grasses. Does not recruit from seed.</td>
</tr>
<tr>
<td>Tall fescue (<em>Festuca arundinacea</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mediterranean types</td>
<td>450</td>
<td>New Mediterranean types still being assessed for long term persistence</td>
</tr>
<tr>
<td>- Temperate types</td>
<td>650</td>
<td></td>
</tr>
<tr>
<td>Cocksfoot (<em>Dactylis glomerata</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mediterranean types</td>
<td>450</td>
<td>Generally only persisting for long periods at high rainfall. Can recruit from seed.</td>
</tr>
<tr>
<td>- Temperate types</td>
<td>700 S, 800 N</td>
<td></td>
</tr>
<tr>
<td>Perennial ryegrass (<em>Lolium perenne</em>)</td>
<td>700 S, 800 N</td>
<td>Generally only long-lived under very high rainfall conditions. Relies on regeneration from seed for persistence</td>
</tr>
<tr>
<td>Species</td>
<td>Minimum rainfall (mm)*</td>
<td>Some features</td>
</tr>
<tr>
<td>-------------------------------</td>
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<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Legumes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subterranean clover</td>
<td>375 S, 600 N</td>
<td>Annual, relying on hardseed for persistence. Three subspecies – subterraneum</td>
</tr>
<tr>
<td>(Trifolium subterraneum)</td>
<td></td>
<td>(acid tolerant), yanninicum (waterlogging tolerant) and brachycalycinum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(suited to alkaline soils).</td>
</tr>
<tr>
<td>White clover (Trifolium repens)</td>
<td>375 S, 600 N</td>
<td>Perennial, usually short-lived unless under very high rainfall conditions –</td>
</tr>
<tr>
<td></td>
<td></td>
<td>needs summer incidence of rainfall to survive. Seed production important in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>summer conditions.</td>
</tr>
<tr>
<td>Lucerne (Medicago sativa)</td>
<td>350 S, 400 N</td>
<td>Limited in higher rainfall zone by soil pH and waterlogging.</td>
</tr>
<tr>
<td>Strawberry clover</td>
<td>600 S, 650 N</td>
<td>Perennial, minor component of sown pastures but waterlogging and salinity</td>
</tr>
<tr>
<td>(Trifolium fragiferum)</td>
<td></td>
<td>tolerant.</td>
</tr>
<tr>
<td><strong>Herbs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicory (Chicorium intybus)</td>
<td>600 S, 750 N</td>
<td>Usually only 2-3 years persistence.</td>
</tr>
</tbody>
</table>

**Ley-farming zone**

This zone is commonly called the wheat-sheep zone. The pasture phase is short, ranging from 1 to 5 years in rotation with a cropping phase of similar duration. In Western and South Australia, for example, the individual phases commonly last only 1 or 2 years, pastures regenerating from hard seed in the soil. In New South Wales and Victoria, a 3- to 4-year phase is common, the pasture species being resown at the end of each cropping phase. The feed base for sheep production in this zone includes pasture, grazing crops (mostly cereals), crop stubbles and supplementary feed.

Commonly, annual legumes, notably subterranean clover, various medic species, balansa clover and serradella are sown depending on climate and a range of edaphic factors (Figure 18.2). Increasingly, the perennial legume lucerne (Medicago sativa) is sown with or without these annual species on appropriate soils (i.e. non-waterlogging with pH (CaCl$_2$) > 5) and underpins the most profitable sheep production enterprises. Its drought-tolerance and deep tap-root enable the production of highly digestible feed in response to summer and autumn rainfall, thereby markedly improving animal production (Wolfe and Southwood, 1980, Wolfe et al., 1980).

The dry summer period characterises the area and restricts the survival of perennials, particularly in the lower rainfall environments where cropping is also marginal. The dominant annual grasses are exotic species and are mostly present as volunteers and include annual ryegrass (Lolium rigidum), barley grass (Hordeum leporinum), silver grass (Vulpia spp.) and brome grasses (e.g. Bromus mollis).

Unlike the permanent pastures of the high-rainfall zone, pastures in a farming rotation are managed to ensure legume-dominance, with grasses being discouraged. Because of their short duration, long-term stability is not as critical. The pasture phase has several purposes. As well as providing feed for livestock grazing, it is a major source of nitrogen for the cropping phase, contributes to soil structural stability and can be managed to assist in weed and crop disease control (Robson, 1987).

Significant grazing may be provided during the winter months by oats, barley and winter wheats. This option provides high quality feed for a brief period in winter during which pasture growth has declined due to low temperatures (Virgona et al., 2006).
The pastoral zone
This zone lies inland from the ley-farming zone. The lack of reliable and effective rainfall is the major constraint to production. Scope for cropping and the establishment of improved pasture species is limited. The environment is highly variable. Paddock sizes are large and the scope for management is generally restricted to manipulation by location of watering points (Finch et al., 2006), varying livestock numbers (Hunt, 2008) and species, and by the use of fire (Craig, 1999).

The major sheep-grazing areas in this zone are the shrub steppe communities comprising saltbush (*Atriplex* spp.) and bluebush (*Maireana* spp.), which are located in the south, and the arid tussock grasslands comprising mainly Mitchell grasses (*Astrebla* spp.), located in the north-east. Grazing is mainly confined to the associated species, usually ephemerals, which occur after rain. Descriptions of the species concerned are given by Cunningham et al. (1981). Sheep also graze the mallee areas located along the southern areas of the Australian rangelands, the semi-arid woodlands of the eastern rangelands and the mulga woodlands in the west. These areas are described in detail in Harrington et al. (1984).

4.2 Pasture improvement
Native pastures are well adapted to their environment but their herbage dry matter production is small. In general, they consist mainly of grass species that are adapted to low soil fertility. They do not withstand prolonged heavy grazing without significant changes in botanical composition (see Moore, 1970). Animal production from native pastures is limited by the low quantity and quality of herbage on offer for much of the year. Herbage production ranges from 1 to 4 t/ha/year (Lazenby and Swain, 1969), but is largely un-utilised because it is produced over a 2-3 month period and rapidly deteriorates in quality and digestibility following flowering. Hence stocking rates are necessarily low, in the absence of livestock trading, because they are geared to the extensive non-productive periods of the year. Pasture quality deterioration can be further accentuated by the grazing out of more palatable species. Every year, long periods of feed shortage occur, interspersed with short periods of herbage availability far in excess of livestock needs.

Nevertheless, such native pastures can play a valuable role if well managed, particularly in low input grazing systems. They are well adapted to their environment and therefore provide ground cover where other species might struggle. The native perennial grasses, by virtue of their perenniality, help to reduce groundwater recharge and hence soil acidification rates, and their root systems aid soil structural stability.

Establishment of improved pastures
Activities range from over-sowing a pasture legume into existing native swards to the complete destruction of such swards (using cultivation and/or herbicides) and replacement with legumes or legume/grass combinations. The key, however, is the introduction of the legume component, together with superphosphate (to provide phosphorus and sulphur). Molybdenum is also required in the high-rainfall (>550 mm), acid soil areas. The legume needs to be adequately inoculated with *Rhizobium* bacteria so that nitrogen fixation takes place to raise soil fertility. The species and variety chosen should be well adapted to the environment and establishment method.

In much of the high-rainfall country, aerial pasture establishment is necessary because of the terrain involved. Large areas of land can be sown quickly, but success depends on:

- moisture availability (sowing during the wet season so as to prevent seedling desiccation);
- removing competition (by heavy grazing, burning and the use of appropriate herbicides);
- choice of species;
- leaving standing litter (the litter provides a more humid environment for the seed, thereby reducing desiccation, and also provides a barrier against seed movement at germination to facilitate soil penetration by the radicle);
- seed treatment (lime coating may improve seed moisture conditions, protects *Rhizobium* bacteria against desiccation and fertiliser damage and restricts seed theft by ants; insecticides compatible with the *Rhizobium* bacteria can be used to minimise this).

A detailed discussion of these issues is provided in Vere and Campbell (2004).

The sowing operation is a crucial step in successful pasture establishment. Usually pasture seeds are small and produce weak seedlings so they are sown at shallow depth. However, in many...
situations, including under-sowing with cover crops, the pasture seed is sown from a small seeds box onto the soil surface and covered with harrows or a levelling bar. This can result in the seed being buried over a range of depths (0-5 cm), leading to poor and variable establishment (30% or lower). The use of a band seeder enables the seed to be precision-planted at shallow depth (Butt, 2004) next to, but not in contact with, a band of fertiliser to avoid damage.

In drier areas, including parts of the pastoral zone, opportunities exist for introducing improved species. Establishment is difficult and slow and is often inhibited by lack of fencing to control animal access. The environment is very fragile and therefore prone to erosion. Usually the existing vegetation needs to be retained for stability, and sometimes for protection of the new seedlings. Successful techniques involve facilitating the accumulation of water near the sown seed. These include furrow sowing, contour ploughing, chequerboard ploughing, ponding and pitting (Cunningham et al., 1978).

Pasture establishment determines the lifetime productivity of the pasture and hence livestock production. Care must always be taken to ensure adequate moisture supply and control of competition. However, even if initial establishment is successful, poor selection of species can be a major limitation to persistence of the sown species. In permanent pastures of the southern slopes in NSW, Virgona and Hildebrand (2006) found that most of the sown species did not persist to acceptable levels. This may be viewed as a persistence issue but in practice the management decisions leading to poor pasture persistence in this respect are made at establishment.

**Early grazing management**

Grazing of new pasture swards should not be undertaken until the plants cannot be pulled from the soil. This usually coincides with a height of about 10 cm for perennials. Annuals have more vigorous seedlings and tend to establish more quickly. Early grazing or mowing, once the plants are anchored, encourages tillering of grasses provided there is not complete defoliation. This defoliation may reduce growth rate, but weed control assists the establishment of desired species. For summer-dormant species like phalaris, early grazing can be harmful as it may decrease the production of dormant buds, thereby reducing summer survival.

It is not advisable to make hay from first-year pastures as it may reduce lifetime performance due to defoliation and interference with seed set. Management practices, such as frequent grazing before flowering (Figure 18.5) and weed control (Figure 18.6) should be used to encourage pasture seed set (Cregan, 1985), particularly with aerially sown pastures, which should not be grazed until after seeding down the first time.

**4.3 Grazing management**

The grazing management of sheep involves manipulating the availability of herbage as economically as possible. Different systems have been discussed and aspects of fodder conservation, forage crop production, weed control and irrigation considered. No pasture system is always best and all these issues need careful evaluation in the context of individual properties.

It is very difficult to provide any robust grazing management rules, especially when the demands for growing pasture in a variable climate and the nutritional demands for raising profitable livestock often conflict. So perhaps one of the rules might be "there are no rules!"

There are however principles of grazing management and, because grazing management usually has linkages to virtually every aspect of farm management, the inter-relationships are complex. This topic highlights those principles which have been discovered in research and also applied by graziers. There is no absolute answer to questions about grazing management. The central conundrum of grazing management is, "how do you match the conflicting needs of a pasture which grows variably in response to climate with the more or less constant needs of the grazing animal without destroying the natural plant and soil resources which support livestock enterprises?

As soon as fences withhold animals on less than the whole farm, we are limiting the supply of feed to those animals. In principle, if we were to have a farm with no fences at all then the animals would have absolute choice of what they ate across that whole farm. So, when we restrict animals to less than the whole farm (for any reason), management is limiting, at least to some extent, the ability of the animals to choose their diet.
The manager needs to be confident that his/her decisions to manage grazing will provide benefits to their overall farm operations. You need to know how to resolve the dilemma of looking after the pasture whilst also satisfying the conflicting demands of grazing animals. This is stated succinctly by Willoughby (1970):

"Any ... system of grazing management other than continuous grazing requires that the stock be restricted for a time to less than the whole food supply available and thus introduces the risk of current animal production being depressed. For a management system to be superior to continuous grazing, subsequent access to the previously protected area or material must more than compensate for this prior depression." (Willoughby, 1970).

This statement clearly shows that any deprivation that causes the animal to restrict its dietary intake must be more than compensated for by the additional growth and/or maintenance of a desirable botanical composition in the pastures that are rested for any period. Of course, when animals first enter a rotationally grazed paddock where a lot of feed is present (say more than 3000 kg DM/ha), they will not initially compete for feed with each other so their intake can be high. But, at high stocking densities, at times as high as several hundred dse/ha, the competition for feed is intense and so they will be competing for feed and thereby reducing their intake within a few days.

The value of improved pastures in raising productivity is emphasised, provided due attention is given to the establishment phase. Subsequent productivity will depend on grazing management practices, including stocking rates and weed management, which is too often overlooked particularly with respect to long-term advantages. Management to maintain adequate soil cover and botanical stability is critical to long-term productivity.

Key objectives in grazing management in the high-rainfall and ley-farming zones include:

- profitability of the enterprise
- pasture stability
- low animal stress
- preservation of the natural resources.

The total value of a pasture is expressed in its ability to produce animal product for the expected duration of the pasture phase. Sustaining animal production levels necessarily relies on maintenance of plant productivity through pasture botanical stability.

**Stocking rates**

The most dominant influence on pasture productivity is stocking rate. At low stocking rates considerable forage is wasted and there is little opportunity to exercise pasture management. Consequently, selective grazing occurs and weed invasion results. During seasonal herbage production peaks, quality of forage on offer declines quickly unless the excess pasture is removed for fodder conservation. At low grazing pressures fertiliser inputs are likely to be uneconomic.

At high stocking rates, risks are increased and higher management skills are required. Over-grazing can remove desirable species from the sward and increase the risks of soil erosion and invasion by unpalatable species. Soil compaction by livestock can occur, particularly during wet weather (Morley, 1981). While high grazing pressures for short periods can be beneficial for weed control, long-term use is likely to require increased expenditure on fencing, yards, water, labour (Sturgess, 1973) and fertiliser (Humphreys, 1972).

Thus stocking rate largely determines livestock production per hectare as well as affecting pasture availability and composition. The economic optimum stocking rate is lower than the biological optimum (White, 1981; Figure 4.1). It also differs depending on the enterprise. Sheep continue to grow wool, even when losing body condition (Wheeler and Hutchinson, 1973). However, ovulation rates and lamb survival are reduced with increasing grazing pressure. Maiden ewe replacements need to be at joining weights by a prescribed time, and this determines the extent to which stocking rates can increase. For meat production, individual performance determines the time taken to reach marketable weight. Wool producers running wethers can therefore sustain higher stocking rates than breeders or prime lamb producers (Sturgess, 1973).
Farmers tend to adopt stocking rates much lower than those indicated by research (White, 1981). McArthur and Dillon (1981) suggested that farmers prefer to maximise the utility of their income (that is, personal goals, attitudes to risks, etc.) rather than net profit. Although adoption of low stocking rates implies a risk-avoidance policy, risks may increase because cash reserves are not increased sufficiently in good seasons to get through a poor season (White and Morley, 1977).

There have been several estimates of pasture capability benchmarks based on rainfall. French (1987) indicated that a stocking rate of 1.3 DSE/ha per 25mm of average annual rainfall in excess of 250mm/year would be sustainable. Court (1998) refined this to 0.8 DSE/ha per 25mm in excess of 250mm for low fertility pastures and 1.3DSE for high fertility pastures whilst Chapman et al. (2003) indicated 1.8 DSE for the higher rainfall zone of south east Australia on improved pastures where there was the option of adjusting animal numbers in relation to feed supply and animal condition. The maximisation of water use efficiency in pastures has been reviewed by Singh et al. (2003) for the high rainfall zone in southern Australia.

Thus stocking rate is one of the most important determinants of the profitability of a livestock enterprise. At high stocking rates, wastage of pasture is reduced - hence more of the plant production is utilised by the animals. At very high stocking rates, the pasture fails to support the animals and deaths can occur.

In Australia, year-round stocking rates on highly improved pasture can be as high as 15 sheep/ha and sometimes even more. The more productive a pasture is, the more complicated the management needs to be.

Any stocking of newly sown pastures should be lenient until the pasture plants are well established with a strong root system. With surface sown pastures, the pasture may need to be left ungrazed for a year or more.

There is an interaction between the stocking rate and gain per head and per hectare and the types of pastures which the animals are grazing, as well as the nutrient inputs into those pastures. It is the type of pastures and the nutrition of those pastures that largely determines their potential for growth, particularly in producing highly digestible green leaf. This is one of the key principles of
this whole section on livestock production that ruminant livestock production depends on the availability of digestible green leaf.

Think about the types of pastures that your animals graze. How often are they green? When they are green, what is their digestibility? When they are dead, what is their digestibility? How easy are the pastures for the animals to bite, chew and digest? Do they have any anti-nutritional components in the forage that might limit animal production? Of course species vary enormously in these attributes and hence it is crucial that you understand for your area and your situation those species which have the capacity to produce the most digestible green leaf over the long term.

There is little point in producing masses of high quality feed that only lasts for a few weeks when it may be possible to have other species grow over a more extended period with perhaps a somewhat lesser peak level of quality feed available. Thus grazing management decisions necessarily involve compromise.

At low stocking rates, grasses are favoured in mixed pastures whereas at high stocking rates, clovers and other broadleaf plants tend to predominate.

The plant species can determine the profitability of an enterprise at stocking rates near the optimum. For example, phalaris persists better under grazing than cocksfoot and tall fescue which are better than ryegrass.

The choice of stocking rate for a particular area should be made with whole-farm profitability in mind as stocking rate affects many things including the survival of perennial pastures, the amount of fodder conserved or purchased, the amount of stock trading, the degree of risk, etc.

The most important determinant of stocking rate is the growth rate of the pasture. Stocking rates affect production per head and per hectare and optimum rates will vary with time and level of inputs. Thus an ‘optimum’ stocking rate is an elusive goal.

Weed management

Managers may take little notice of any weed problem that builds up in pastures. The presence of particular weed species sometimes indicates certain conditions. For example, grass weeds or thistles in a legume-based pasture indicate that soil nitrogen status is high. Dandelions or sorrel may indicate a lack of competition caused by a soil acidity problem. The presence of weeds generally reduces the productive capacity of the land, sometimes directly affecting sheep productivity. For example, barley grass can cause a grass-seed problem in lambs; photosensitisation can occur in sheep grazing St John’s wort; and heliotrope and Paterson’s curse can cause liver damage, resulting in chronic copper poisoning. Alternatively, these plants compete with more desirable pasture species thereby reducing pasture quantity and quality. This becomes an increasing problem because the desirable pasture species are selectively grazed and re-grazed.

Economics of weeds in pastures

Weeds represent a considerable cost burden to the enterprise. This cost comprises the financial expenditure on chemical and non-chemical (e.g. grazing, slashing, tillage) control as well as the opportunity cost measured as the value of lost production due to the weed infestation (Sinden et al., 2004). Estimates of the control costs to the Australian industry are in excess of $400 million per year (Table 4.2).

<table>
<thead>
<tr>
<th>Enterprise</th>
<th>Crop and pasture chemical expenditure on weeds $/ha</th>
<th>Crop and pasture chemical expenditure on weeds $m/industry</th>
<th>Non-chemical costs of weed control $/ha</th>
<th>Non-chemical costs of weed control $m/industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grains/livestock</td>
<td>10.56-12.54</td>
<td>218-259</td>
<td>6.93</td>
<td>143</td>
</tr>
<tr>
<td>Sheep/beef</td>
<td>0.51-0.57</td>
<td>22-24</td>
<td>0.33</td>
<td>14</td>
</tr>
<tr>
<td>Sheep</td>
<td>0.45-0.50</td>
<td>24-27</td>
<td>0.29</td>
<td>16</td>
</tr>
</tbody>
</table>

Source: Sinden et al. (2004).
The opportunity costs can be considered in terms of reduced carrying capacity per hectare. Based on an estimated production loss of 5% (Sinden et al., 2004) this equates to more than $400 million per year plus the discount in wool due to vegetable fault. The latter is difficult to attribute to weeds because of the contamination by clover and medic burr but substantial benefits can be realised by reducing the contamination (Rabjohns, 1986). Where toxic weeds are palatable to livestock, it is economic to eliminate them because the costs of stock losses tend to be large in relation to herbicide costs (Hyde-Wyatt, 1978).

In some cases the infestation of a particular weed is undesirable but is not economic for individual landholders to remove. For example, Savory and Soper (1973) found that an initial cover of 20% of docks (Rumex spp.) was needed before pasture yields were improved by their control. Vere and Medd (1979) estimated the annual cost of controlling nodding thistle (Carduss nutans) was greater than the estimated production loss whilst Menz and Auld (1977) also record that the eradication of galvanised burr (Sclerolaena birchii) from the rangelands of eastern Australia was uneconomic for individual farmers.

Other studies have shown favourable returns. The best-documented economic study on pasture weeds has been on the perennial grass, serrated tussock (Nassella trichotoma), the most serious weed of the New South Wales tablelands (Campbell, 1992). Heavy infestations have reduced carrying capacity by up to 90% (Vere and Auld, 1979). The costs of replacement of the weed with pasture legumes and perennial grasses, together with maintenance until the pasture becomes dominant, are considerable (Vere and Campbell, 1984). Where heavy infestations occur it may take 10-20 years before the pasture establishment costs are repaid. However, despite this Vere et al. (1980) estimated that the net social benefits to the community of widespread control were $187-$334 million. For species such as serrated tussock, under the noxious weeds provisions, landholders are required to undertake control measures or be liable for prosecution, even if they are uneconomic in lower-fertility and low-rainfall areas.

Consideration should also be given to the long-term effects, management implications and community benefits. Conservative stocking rates may encourage the development of a weed problem through selective grazing practices, and control measures will have no effect on a non-existent feed shortage.

4.4 The science behind grazing management

In his book, Grazing Management – Science into Practice, John Hodgson (1990) describes in great detail the principles of grassland and grazing management and the ecology of grazed pastures. A summary of some of his key principles follows.

Figure 4.2 Interactions between the stages of production in grazing systems. Source: Hodgson (1990).
Contemplate the interactions between the various components contained in this figure and the “butterfly valves” which moderate rates of flow around the diagram. The processes such as growth, senescence, consumption, digestion and excretion largely govern grazing system productivity. When animals graze pastures, they consume the most digestible green leaf first.

Consider the diagram below and think about how much of the photosynthetic capacity would be removed if most of the leaves were to be eaten. Ryegrass is best grazed at the 3-leaf stage whereas prairie grass is best grazed at the 4-leaf stage? Why do you think that might be?

Figure 4.3 Illustration of an established plant of perennial ryegrass with four tillers. The production of tillers allows grasses to tolerate grazing as new tillers arise in response to defoliation. Source: Hodgson (1990).

How many leaves are on each of the ryegrass tillers? Would there be enough for this plant to be grazed without threatening its persistence?

Think about where the energy comes from for regrowth when a plant has all of its leaves defoliated. This energy is built up in the stem bases of grasses when the plant reaches the 3 or 4-leaf per tiller growth stage.

Figure 4.4 A white clover stolon showing leaf development and stolon branching. Stolons allow plants to avoid grazing and are an important mechanism for white clover survival under grazing. Source: Hodgson (1990).
What would happen if stolons didn’t root at the nodes?

Is a plant like white clover tolerant of grazing?

Why is a legume in a pasture so important? Is white clover a perennial? If white clover dies due to extreme drought how can it regenerate in a pasture? UNE Students should have the answers to these questions from prior learning (e.g. Agronomy 211 at UNE).

Figure 4.5 Cross-section of a mixed sward of grass and clover. Source: Hodgson (1990).

The location of green digestible leaf, dead leaves, stem, etc. in the plant canopy is a key to how readily an animal can select a quality diet. There is a very strong interaction between the light interception by a grass sward and therefore its capacity to carry out photosynthesis and its leaf area index (LAI), as shown in the following figure. (Figure 4.6)

Figure 4.6 The relationship between Leaf Area Index (LAI) and light interception by a grass sward. Source: Hodgson (1990).

At a LAI of 4-6, almost all light energy is captured. Thus, an overgrazed sward without much leaf area will not be able to utilise all of the incident light.

The issue of selective grazing is an important one when considering grazing management. Obviously, the greater the opportunity an animal has to select its own diet, the higher the quality diet it is able to eat. In intensive rotational grazing systems where many animals are grazing in one paddock, all animals are competing for a limited resource and hence their capacity to selectively graze and thereby to select a high quality diet is restricted. This is a key issue relating to the productivity of individual animals when grazing swards under rotational management systems.
contrast, when animals have access to large areas, such as when all the gates of a farm are open, they have maximum opportunity for selective grazing and hence choosing the best diet from their perspective. There have been some interesting free choice pen feeding studies in NZ, where sheep given an unrestricted wide selection of feed choices, eat a balance of feeds which meet their protein and energy needs.

The accumulation of increasing amounts of herbage over time is well-known in grazed pastures and is depicted below.

You will note the similarity between the above graph and the stages of growth depicted in booklets such as the PROGRAZE literature and in literature relating to cell grazing which refers to three phases (1, 2 and 3) of growth of a pasture (see Figure 16.7). The figure above shows the very steep rise in the net accumulation of live pasture up to a maximum; beyond that point there is a decline of green pasture and an increasing amount of senescent or dead tissue.

**Figure 4.7** The time sequences of (a) herbage accumulation and (b) tissue turnover in a cut sward. The cumulative changes in herbage mass (kg DM/ha) in a sward over time during a period of recovery growth after a cut close to ground level and (b) the corresponding changes in net accumulation due to growth and losses due to senescence and decomposition. Source: Hodgson (1990).
Obviously there is a compromise between having sufficient herbage available and its greenness and digestibility and hence the rate of intake with which an animal can eat that pasture. Not only does this affect the intake of a grazing animal, but it also affects the rate of growth of the herbage; this is depicted in figure 4.9 below.

Figure 4.9 The influence of sward surface height and LAI on rates of herbage growth, senescence and net production on continuously stocked swards. Relationship between sward height, LAI and rates of herbage growth, senescence and net production in swards grazed by ewes and lambs under continuous stocking. Source: Hodgson (1990).

The amount of herbage intake that an animal can eat is closely related to its capacity to grow wool and to gain weight. As described by Hodgson (1990), herbage intake is affected by the digestion rate, which is related to the quality and maturity of the herbage eaten, the physical structure of the sward canopy and the demand for nutrients and digestive capacity of the livestock eating the pasture; this latter factor is determined largely by the age and productive state of the animal. Intake is also affected by the fouling and trampling of pastures brought about by grazing animals having affected the pasture prior to an animal arriving at a particular plant or part of a sward.

In general, liveweight gain is almost linearly related to herbage intake. Note the similarity in the figure below between the herbage intake by various classes of animals and their weight gain or milk yield as it is affected by the height of the sward being grazed. This demonstrates that herbage...
intake is closely related to weight gain or milk yield. Although not shown here, it is also closely related to wool growth, as wool is a product of protein synthesis just as is milk and meat.

In his text, Hodgson (1990) explains that the critical values of the sward height for continuously stocked animals are generally lower than for rotationally grazed animals. The critical value for ewes and lambs is 4-5 cm in spring under continuous stocking and 6-7 cm under rotational grazing. When pastures are rotationally grazed, animals require a taller pasture in order to maintain adequate levels of herbage intake close to the maximum compared to those under continuous stocking. Of course this will very much depend upon the physiological state of the animals and the species and quality of the pasture and its maturity, as well as its leafiness.

Figure 4.10 Relationships between sward surface height and (a) herbage intake or (b) animal performance in grazing animals under continuous stocking management. Intake and performance are expressed in relative terms. Note that the intake of ewes and lambs starts to fall at sward heights below 7 cm. ‘C’ indicates the critical height for different classes of animal. Source: Hodgson (1990).

It is important to attempt to maintain ideal sward conditions to maximise pasture growth but, in the face of variable growth rates, this is extremely difficult to achieve under Australian conditions. Nevertheless, as shown in Figure 4.11 below, ideal conditions have been described for sheep as those swards which are 4 to 5 cm tall.
Another dilemma is presented in the figure below, which shows a negative relationship between intake and utilisation. You will note in the MLA book ‘Towards Sustainable Grazing’, that producers need to increase utilisation of pastures and yet get high per animal performance. This graph points out how difficult this is because, to increase utilisation, one needs to reduce the herbage allowance, which is associated with lower intake. Hence, once again, there is a need for a compromise between intake and utilisation.

This very much relates to stocking rate and/or carrying capacity of the farm. As is shown in Figure 4.13, as we increase the stocking rate we tend to depress net production, but we also see an associated decline in losses through senescence as we utilise more of the pasture. Obviously, at extreme stocking rates, growth will crash to zero.
Figure 4.13 The influence of stocking rate on rates of herbage growth, senescence and net production. Source: Hodgson (1990).

An idealised diagram showing the relationship between gain per sheep and gain per hectare is shown in figure 4.14 below. This diagram shows a linear decline in gain per sheep as stocking rate increases. This is not strictly true as, at low stocking rates, there is little competition between animals. Nevertheless, as competition occurs, per animal performance will certainly decline.

Figure 4.14 The relationship between stocking rate and (a) individual performance or (b) animal production per unit area over a grazing season. Source: Hodgson (1990).

Grazing management also has impacts on the survival and death of internal parasites of sheep and there has been much research conducted on how grazing management affects the health of grazing animals. In general, in order to kill the larvae of internal parasitic worms of sheep, it is necessary for an extended rest period to occur if parasite numbers are to decline significantly. However, the better the nutrition of the livestock grazing infected pastures, the better their capacity to tolerate chronic infections of internal parasites.
The most commonly researched systems have been rotational grazing and continuous grazing of improved pastures, which have generally produced similar results, with the exception of the need to rotationally graze lucerne (Lodge, 1991). The crown of the lucerne plant is accessible to grazing sheep so it may be completely defoliated. Repeated and complete defoliation eventually exhausts root reserves. Rotational grazing, providing a rest period over 5 weeks during the rotation, is required. While a three-paddock system is sufficient in the high-rainfall zones (McKinney, 1974), a four-paddock system is required in areas where annual rainfall is less than 500 mm (FitzGerald et al., 1980).

Subdivision into paddocks is necessary for any grazing management. In Australia, animal production is not always increased by subdivision (Elliott, 1966). There may be some benefit from reducing the transfer of nutrients by livestock to camp sites, and from disease control. These seldom justify the cost of fencing, but subdivision allows for the separation of different flocks. In recent times there has been greater interest in cell grazing (Earl and Jones, 1996) and technograzing (Hebart et al., 2004) whereby the area is intensively subdivided and flocks are concentrated on the cells for a few days and then the area is rested for a prolonged period as the other cells are sequentially grazed. Benefits identified include botanical stability and animal production.

Efficiency of crop production is reduced as the paddock sizes become smaller. In the pastoral zone, flocks are more likely to be controlled by location of watering points, as there are limits to the distances from water animals can graze.

Almost without exception, experimental comparisons between rotational and continuous grazing have been made with strictly-adhered-to management systems. In practice, farmers have the flexibility of changing from one system to the other as deemed necessary, resulting in more intermittent grazing patterns. Research generally does not take into account aspects such as the need for sheltered paddocks for lambing, the use of stubbles, or grazing of paddocks earmarked for cropping, thereby spelling regularly grazed pastures. Spelling pastures can help rapid

Figure 4.15 Methods of grazing management. Diagrammatic depiction of various methods of grazing management from set stocking through to rotational grazing. Source: Hodgson (1990).
regeneration of annual species in autumn in some years, thus providing extra feed in winter and early spring.

Much of the early research on grazing management systems was focused on animal production, with little attention paid to the effect on pasture. Little advantage was found for rotational grazing (eg. Morley et al. 1969) whereas later research at Broadford, in Victoria found that rotational and intensive grazing of phalaris pastures led to greater animal production, greater phalaris persistence and higher levels of ground cover (Warn and McLarty, 2001). In lucerne-based pastures the need to apply rotational grazing has been unequivocal (Southwood and Robards, 1971) with respect to lucerne persistence.

Rotational vs continuous grazing
Continuous grazing is where animals graze a particular area over more or less the entire year. It is the least controlled of the grazing systems. Rotational grazing involves moving the stock from paddock to paddock thus permitting each grazed area to recover somewhat before another grazing; it requires a higher investment in fences and watering points than continuous grazing.

For cost reasons, there is a tendency for researchers to use small paddock studies, often using fixed rotational times, in their investigations compared to farmers who are working at a very different scale and who also are likely to use quite flexible rest periods in any rotational grazing that they implement. The consequences of these two differences of space and of flexibility in rest period are key to why there are differences between the scientific literature and practical experience.

Rotational grazing is claimed to improve the botanical composition of a pasture, reduce animal ‘camp’ effects, result in less waste, and create higher quality pastures. Under Australian conditions, the supposed benefits of rotational grazing over continuous grazing have not been proved in practice except where the species are intolerant of continuous grazing (e.g. lucerne) or where stocking rates are very high. This may be due in part to the fact that under continuous grazing systems, animals can be more selective in their grazing whereas, under an intensive rotational grazing system, animals are forced to eat what is on offer. Following rotational grazing, the grazed paddock is shut up and allowed to regrow for 21-90 days depending on the time of year and growth rate. In New Zealand, some sheep graziers have adopted a rotational grazing system where large numbers of stock are moved each day to a rested pasture paddock.

Writing about the management of native pastures in Queensland, Scattini et al. (1988) summarise the words of Wilson et al (1984) thus:

- “rotational grazing systems do not increase short-term animal production
- the botanical change brought about by a grazing system must either increase the density of desirable species or replace an undesirable species with a desirable one
- grazing systems are more likely to lead to a useful change in botanical composition when the vegetation contains a number of perennial grasses
- rotational grazing systems favour perennial species and continuous grazing favours annual species
- the advantage of a grazing system requires many years to become evident, and
- the adoption of grazing systems requires additional expenditure in fencing, watering and stock movement.”

Cell grazing
Cell grazing is a particular form of intensive rotational grazing. It involves a farm being divided into many paddocks which then allows each paddock to be intensively grazed followed by an extended period of rest. Claims made for such systems include the importance of hoof action in restoring hydraulic function, the importance of plant succession and the redistribution of nutrients – all of which are claimed to allow higher stocking rates. There is much debate about such systems and there is little scientific evidence to support these claims.

Ultimately, it should be remembered that when one forces paddocks to be rotationally grazed, one forces the animals to eat a restricted diet compared to continuous grazing where animals theoretically have greater choice of diet. This can have impacts on productivity per head and per
hectare. Ideally, one wants good per animal productivity without compromising overall per hectare performance.

Most farmers practising intensive rotational grazing with long rest periods would rarely have a rest period any longer than 100 days. However, in some situations rest periods can extend as long as 200 days (e.g. if the graze period is 3 days followed by a 100 day rest then that ‘cell’ will require about 33 paddocks). Whilst it may seem from the pastures point of view desirable to have such a long rest period, one has to acknowledge that, whenever grazing animals are not grazing a paddock, then that part of that farm is not being utilised on any of those days by a livestock enterprise which generates money for that farm.

Figure 4.16  Diagram of a ‘cell grazing’ system whereby stock are moved from paddock to paddock using intensive rotational grazing followed by a long period of rest. Cells may have 30 – 50 paddocks per cell allowing rest periods of up to 100 days or more.

The profitability of grazing systems is more likely to be affected by the species sown, the fertiliser used and the stocking rate than by the grazing system used.

Negative effects of grazing
Treading injury has a cumulative effect during the grazing. Damage is greatest under wet conditions. In a study of the impacts of treading, reductions of pasture yield were by 6, 9, and 12% in years 2, 3, and 4 respectively compared to year 1 when the pasture was newly sown. The zone of compaction is about the top 15 cm. However, stocking rate doesn’t appear to have a large effect. It is possible for vigorous pasture growth to rehabilitate compacted soil but this can take some years, depending on growing conditions.

Table 4.3 Influence of sheep treading on the regrowth (kg/ha) of a mixed sward at Mount Cotton, Queensland. Source: Humphreys (1981).

<table>
<thead>
<tr>
<th>Stocking rate (sheep/ha)</th>
<th>Lotiononi s bainesii</th>
<th>Digitaria decumbens</th>
<th>Other species</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>440</td>
<td>430</td>
<td>20</td>
<td>890</td>
</tr>
<tr>
<td>7</td>
<td>310</td>
<td>420</td>
<td>30</td>
<td>750</td>
</tr>
<tr>
<td>14</td>
<td>150</td>
<td>430</td>
<td>30</td>
<td>610</td>
</tr>
<tr>
<td>21</td>
<td>40</td>
<td>470</td>
<td>20</td>
<td>520</td>
</tr>
<tr>
<td>28</td>
<td>10</td>
<td>490</td>
<td>10</td>
<td>510</td>
</tr>
<tr>
<td>Significance, P&lt;</td>
<td>0.001</td>
<td>N.S.</td>
<td>N.S.</td>
<td>0.001</td>
</tr>
</tbody>
</table>

The table above demonstrates the principle that, in general, grasses are far more tolerant of treading injury than legumes.
4.5 Use of pasture assessment/feed budgeting

PROGRAZE courses run by accredited staff in most States up skill graziers to objectively assess the herbage mass and quality of their pastures as well as the condition (or fat score) of their livestock. In this way, graziers are better equipped to manage their grazing systems regardless of their approach to grazing management.

Prograze - extension for grazing management

The two most critical assessments are herbage mass and digestibility. See the Prograzier article on assessing herbage mass. Note that the chart in this article relates pasture height to kg GREEN Dry Matter/hectare – not TOTAL.

Animal and pasture benchmarks are shown below.

Figure 4.17 below shows, for example, that a dry sheep can get equivalent nutrition from 3000 kg DM/ha of 55% digestibility as it can from a pasture with 600 kg DM/ha of 70% digestibility.

Figure 4.17 The relationship between herbage mass and digestibility in providing an equivalent diet for different classes of livestock. Source: PROGRAZE manual.

![Figure 4.18](image)

Figure 4.18 The effect of plant growth stage on crude protein and digestibility of a phalaris pasture. Source: Scott (2006).

Plant growth stage is also important for livestock production. Grazing ruminants require at least 7% crude protein and 55% digestibility for maintenance. For growth they need substantially higher levels. A difference of just 5% in digestibility may not seem much but it has a large impact on sheep productivity, including on wool growth. You can check this out when using GrazFeed software. Thus, it is important wherever possible, to graze pastures that are vegetative, not senesced.
Pasture benchmarks for sheep
The minimum pasture herbage mass levels for the various classes of sheep (and cattle for comparison) are shown in Table 4.4. Note that the benchmark is for green herbage mass – not total.

Table 4.4 Green pasture mass requirements. Source: PROGRAZE manual.

<table>
<thead>
<tr>
<th>Sheep category</th>
<th>Growth stage</th>
<th>Minimum pasture (kg green DM/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry sheep</td>
<td></td>
<td>400-500</td>
</tr>
<tr>
<td>Pregnant ewes</td>
<td>mid pregnancy</td>
<td>500-600</td>
</tr>
<tr>
<td></td>
<td>Last month</td>
<td>800-1000</td>
</tr>
<tr>
<td>Lactating ewes</td>
<td>Singles</td>
<td>1000-1200</td>
</tr>
<tr>
<td></td>
<td>Twins</td>
<td>1400-1600</td>
</tr>
<tr>
<td>Growing stock(^a)</td>
<td>30% (90 g/day)</td>
<td>500-600</td>
</tr>
<tr>
<td></td>
<td>50% (150 g/day)</td>
<td>700-800</td>
</tr>
<tr>
<td></td>
<td>70% (190 g/day)</td>
<td>900-1000</td>
</tr>
<tr>
<td></td>
<td>90% (250 g/day)</td>
<td>1500-1600</td>
</tr>
<tr>
<td>Cattle category</td>
<td>Growth stage</td>
<td>Minimum pasture (kg green DM/ha)</td>
</tr>
<tr>
<td>Dry cow</td>
<td></td>
<td>700-900</td>
</tr>
<tr>
<td>Pregnant cow</td>
<td>7-8 months</td>
<td>900-1200</td>
</tr>
<tr>
<td>Lactating cow</td>
<td>(calf 1-2 months old)</td>
<td>1500-2300</td>
</tr>
<tr>
<td>Growing stock(^a)</td>
<td>30% (0.44 kg/day)</td>
<td>700-900</td>
</tr>
<tr>
<td></td>
<td>50% (0.71 kg/day)</td>
<td>1000-1100</td>
</tr>
<tr>
<td></td>
<td>70% (0.95 kg/day)</td>
<td>1300-1500</td>
</tr>
<tr>
<td></td>
<td>90% (1.20 kg/day)</td>
<td>2200-2300</td>
</tr>
</tbody>
</table>

\(^a\) Growing stock percentage refers to percentage of maximum growth rate of the animal.

Calculation of stocking rate based on pasture supply and demand
When one knows the herbage mass and growth rate, one can calculate the likely stocking rate which that pasture can support. An example calculation is shown below for a situation where ewes are about to lamb.

NB. If a pasture is not actively growing, it can only support livestock grazing until the existing herbage is depleted.

<table>
<thead>
<tr>
<th>Supply</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Present pasture mass</td>
<td>1500 kg green DM/ha</td>
</tr>
<tr>
<td>Less required minimum pasture mass</td>
<td>1200</td>
</tr>
<tr>
<td>Available pasture</td>
<td>300</td>
</tr>
<tr>
<td>Plus pasture growth (42 lambing days X 20 kg DM/ha/day)</td>
<td>840</td>
</tr>
<tr>
<td>Total available pasture</td>
<td>1140</td>
</tr>
<tr>
<td>Less 30% wastage for trampling/fouling</td>
<td>342</td>
</tr>
<tr>
<td>Balance available</td>
<td>798</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Demand</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement 2.3 kg green DM/hd/day for 42 days</td>
<td>96 kg green DM/hd</td>
</tr>
</tbody>
</table>

No. of ewes = Total available/livestock demand

\[=\text{798}/96\]

Stocking rate

\[=8.3\text{ ewes/ha}\]
4.6 Native vs improved pastures

In the recently completed key MLA program, Sustainable Grazing Systems, researchers investigated a wide range of pasture types, inputs and managements. In summing up the pasture findings over 8 sites and 4 years, Sanford (2003) stated:

"Based on the results from the SGS NE (National Experiment), pastures in the HRZ (high rainfall zone) were unlikely to exceed a water-use efficiency (WUE) of 18 kg DM/ha.m. Native and naturalised pastures, by comparison, at best achieved a WUE of about 10 kg DM/ha.mm".

This means that for a rainfall of say 800 mm, the best sown pastures (with fertiliser) could produce 14.4 tonnes DM/ha/year (18 X 800) whereas native and naturalised pastures (with fertiliser) could produce about 8.0 tonnes DM/ha/year (10 X 800). Of course, the cost of sowing pastures in order to get higher yields needs to be balanced against the fact that most native pastures cost relatively little.

The productivity of both native and sown pastures subjected to either continuous or tactical grazing (with and without fertiliser) is shown in Figure 4.19 below. Tactical grazing tends to result in higher levels of perennial herbage.

Figure 4.19 Total, green and perennial herbage mass over a number of years for a range of pasture types and grazing management systems implemented at Carcoar, New South Wales. Source: Michalk et al. (2003).
Table 4.5 shows the economic and resource impact ratings for the systems tested.

**Table 4.5 Economic evaluation and resource impact ratings for the seven treatments tested at Carcoar (Central Tablelands of NSW). Source: Michalk (2003).**

<table>
<thead>
<tr>
<th>Pasture type</th>
<th>Grazing management</th>
<th>Rating of resource impacts</th>
<th>EANR(^{\text{a}}) ($)/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfertilised naturalised</td>
<td>Continuous</td>
<td>+5</td>
<td>179</td>
</tr>
<tr>
<td>Unfertilised naturalised</td>
<td>Tactical</td>
<td>+1</td>
<td>166</td>
</tr>
<tr>
<td>Fertilised naturalised</td>
<td>Continuous</td>
<td>-2</td>
<td>218</td>
</tr>
<tr>
<td>Fertilised naturalised</td>
<td>Tactical</td>
<td>+3</td>
<td>199</td>
</tr>
<tr>
<td>Sown perennial grass</td>
<td>Continuous</td>
<td>+3</td>
<td>250</td>
</tr>
<tr>
<td>Sown perennial grass</td>
<td>Tactical</td>
<td>+4</td>
<td>194</td>
</tr>
<tr>
<td>Chicory</td>
<td>Rotational</td>
<td>+3</td>
<td>235</td>
</tr>
</tbody>
</table>

\(^{a}\)Equivalent annual net return (annualised over 10 years).

It is clear from the above table that the rating of resource impact (the higher the better) and the annualised net economic return was higher on pastures where fertiliser had been added and higher still where sown pastures were used. However, the economic ratings tended to be higher with continuous grazing than tactical in contrast to the resource ratings which showed quite marked improvements due to tactical grazing. Tactical grazing in reality is ‘having a bet both ways’. That is not to say it is wrong – it is valid to continuously graze certain pastures and at other times it makes sense to rotationally graze pastures. It is understanding under which conditions one does either that you will need to read the literature.

**Effects of grazing management on different species**

What species is by far the most well known with regards to requirement of careful grazing management? Any search of the literature or textbook will tell you it is lucerne. Why is that? Well, if one thinks about it … lucerne is a plant which provides an upright living haystack of highly digestible nutrients. Being upright means that the grazing animal can bite off all leaves and stems except for the woody crown. And as it is so high in quality, animals have rapid intake and hence will repeatedly eat any new regrowth from the crown if given a chance. This leads quickly to the depletion of the energy reserves in the plant and ultimately to the plants dying.

What about pasture plants at the other extreme? Do they get grazed out readily? Consider, for example, tussocky poa (**Poa sieberiana**). It is relatively low in digestibility and usually has a lot of senesced leaves of particularly low digestibility. It is difficult to remove through grazing and commonly persists very well in continuously grazed paddocks.

In between, we have many plants that range from very tolerant of grazing (e.g. kikuyu) through to others which can disappear if grazed continuously (e.g. perennial ryegrass).

In the case of the paper by Chapman *et al* (2003) the focus is largely on phalaris (a perennial grass) and subterranean clover (an annual legume). Both these species are relatively tolerant of continuous grazing because they are well adapted to withstanding animals with their prostrate habit under grazing.

The results of this study could well have been quite different if the species under study were different. In general, the more digestible the pasture plant, the more important it is that the plant is rested in between grazings.
4.7 Decision support tools

Models of grazed pastures will ultimately be put into decision support systems which will be capable of making sophisticated predictions to aid graziers to manage risk better. During residential school students will experience the use of decision support systems and especially the use of GrassGro and GrazFeed so that you can gain an appreciation of the linkages between various parts of the grazed ecosystem.

GrazFeed
One of the best tools for assessing the consequences of varying amounts of herbage mass and quality on livestock production is that provided by the Decision Support Tool GrazFeed. GrazFeed predicts animal growth and reproduction based on intake which is linked to herbage mass and quality. This is a computer-based version of the Australian Feeding Standards for Ruminant Livestock. During the residential school you may be given an opportunity to use this Decision Support Tool to evaluate the consequences of varying supplies of herbage mass and quality and legume percentage on liveweight gain and wool growth.

GrassGro
GrassGro is a comprehensive decision support tool, based upon systems science, which provides a powerful tool for understanding complex ecosystems. GrassGro uses daily climate data to drive a soil water and pasture growth model which then interacts with GrazFeed on a daily basis to predict animal growth. Management rules are provided in GrassGro to allow for various joining, shearing dates, stocking rates, etc.

It allows the calculation of plant and animal responses to a wide range of soil and daily weather conditions. It is capable of being adapted for any pasture species in any region of the world although, to date, it has been most thoroughly tested in the high rainfall temperate zone of Australia.

4.8 Remote sensing of feed on offer

Over recent years the technology for measuring pastures from space has improved dramatically with trials extending from Western Australia through to Victoria and now into Queensland. This technology involves satellites being able to scan parts of the earth’s surface with light reflectance detectors measuring various parts of the spectrum, both visible and invisible, including the infrared and near infrared wavelengths. You may be aware that it is common practice these days in laboratories to measure pasture quality using near infrared spectrometers (NIR). These detectors mounted on satellites are basically a flying NIR reporting back to earth with data, which is transformed by computers and can be made available for particular farm areas. This technology is very suitable for measuring paddocks greater than six hectares and is the only way – apart from data captured by flying aircraft – that one can get an integrated assessment of the whole farm’s herbage mass at a particular time.

As this technology improves, not only will herbage mass be measured, but so will herbage quality. These are the two guiding principles influencing animal growth described in the PROGRAZE extension package that has been used so successfully around the various states of Australia. An additional factor that can be measured by remote sensing is an estimate of pasture growth rate; this is one of the key factors governing the stocking density that can be supported by a pasture at any one time.

Thus, ultimately we will have increasingly valuable assessments from space of herbage mass, herbage quality and growth rate and, in time, the pixel size (or resolution) of these images will improve as satellite technology improves. In spite of this technology, you still need to be well equipped yourself with some skills in assessing the herbage mass and quality of pasture and have an appreciation of the likely growth rate of pastures. You would no doubt benefit from taking a PROGRAZE course if you want to improve your pasture assessment skills.
4.9 Sustainability of grazed pastures

What does sustainability mean to you?

One useful view is to consider a pasture or a farming system as one comprised of layers. In order for the system to function properly over time, all its parts need to function well. That is, a whole farm needs to be sustainable. A farm is comprised of its paddocks, soils, pastures and crops, animals, financial viability, human capital, etc; all of these components need to be cared for if sustainability is to be an achievable goal.

Sustainability is a question of balance

Figure 4.20 showing layers supporting a sustainable system. Note the differences in farmer priorities to biophysical importance. Source: Scott et al. (2000).

According to Scott et al. (2000), measures of ‘sustainability’ should include:

- biophysical and
- economic components
- trends over time of natural capital status, and
- assessments of any off-site effects.

Measuring sustainability

Ultimately a complex matrix of sustainability indicators and production benchmarks will need to be met in order to be deemed ‘sustainable’. This is an important current issue for much of Australia’s livestock production areas.

The question of quantifying sustainability has been tackled for grazed pastures by Scott et al. (2000) where the authors compiled data and trends over time for a number of soil, pasture, animal, production and economic parameters. Some of these measurements are summarised here for three different pasture types, all on similar soil and fertilized at the same rate. The pastures were all based on the same original phalaris/white clover pasture sown in 1966. Over time some paddocks had become ‘degraded’ by losing most of the phalaris and white clover. Other paddocks (‘phalaris’) had lost the clover component. The third treatment was also phalaris dominant but had white clover re-established in autumn 1994. These pastures were found to have quite different sustainability characteristics (see Table 4.6).

The combination of a deep rooted perennial grass (phalaris) with a persistent legume (white clover) resulted in more water extracted in autumn (thus a bigger ‘bucket’ to fill up when it rains), least runoff during a storm, more nitrogen at the surface (thus more productive) and yet less at depth (less leaching of nitrate), more wool growth and liveweight gain per head and per hectare and more financial returns. Thus, it was assessed as the most ‘sustainable’ pasture of the 3 compared.
Table 4.6 Some measurements of soil sustainability and livestock production factors in an experiment comparing the sustainability of three different pasture types.  
Source: Scott et al. (2000).

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Units</th>
<th>Degraded pasture</th>
<th>Phalaris pasture</th>
<th>Phalaris/white clover pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water extracted in 4 week drought in autumn</td>
<td>mm</td>
<td>28.0</td>
<td>38.0</td>
<td>51.0</td>
</tr>
<tr>
<td>Run-off following a 106 mm rainfall event</td>
<td>mm</td>
<td>3.0</td>
<td>24.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Mineral N (0-5cm) at Feb-97</td>
<td>µg N/g soil</td>
<td>13.5</td>
<td>13.0</td>
<td>29.0</td>
</tr>
<tr>
<td>Mineral N (40-60cm) at Feb-97</td>
<td>µg N/g soil</td>
<td>1.6</td>
<td>3.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Wool growth</td>
<td>kg/hd/yr</td>
<td>3.0</td>
<td>3.4</td>
<td>4.6</td>
</tr>
<tr>
<td>Liveweight gain</td>
<td>kg/hd/yr</td>
<td>5.5</td>
<td>10.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Stocking rate</td>
<td>dse/ha</td>
<td>9.9</td>
<td>14.0</td>
<td>14.8</td>
</tr>
<tr>
<td>Liveweight gain/ha</td>
<td>kg/ha/yr</td>
<td>54.5</td>
<td>140.0</td>
<td>222.0</td>
</tr>
<tr>
<td>Wool produced/ha</td>
<td>kg/ha/yr</td>
<td>29.7</td>
<td>47.6</td>
<td>68.1</td>
</tr>
<tr>
<td>Gross return/ha (@$1.00/kg LW and $6.00/kg wool)</td>
<td>$/ha/yr</td>
<td>$233</td>
<td>$426</td>
<td>$631</td>
</tr>
</tbody>
</table>

Conclusions on a ‘sustainable’ grazing enterprise:

These authors found that a sustainable enterprise is:

• based on partnership between a nutrient responsive grass and an active legume
• is profitable over the long-term, and
• causes no significant detriment to the plant and soil resources.

A further important principle in sustainability is that it is necessary to survive bad seasons with the farm’s natural capital in good condition.

Ultimately, a sustainable system is one where the farmer lives off his/her ‘interest’ rather than their ‘capital’.

Sustainable grazing enterprises are built on inter-related layers, each supporting the next - with long-term profit being the ultimate aim.

They require sufficient green digestible leaf to be produced by persistent plants. Quality pasture depends on:

• climatic constraints
• pasture species present
• productive capacity of the soil, and
• grazing management.

The last 3 of these can all be managed by the farmer.
Looking after natural capital
In many parts of high rainfall Australia (and in many parts of the world) over clearing for grazing has led to problems for the landscape. Ultimately we must have systems in hydrologic balance. Some state that we need 30% of the landscape under trees as they act as effective ‘water pumps’. However, so do productive deep-rooted pastures. For example, this is being achieved in southwestern Australia using kikuyu as a productive pasture which is capable of effectively tapping into ground water supplies.

Soil is the fundamental productive resource of our farms - we need to build productive pasture systems on a sound foundation by having healthy soils:

A well aggregated soil will allow water to enter readily (infiltrate) and be released easily to plants. This is influenced also by the degree of compaction - measured by soil strength and bulk density. These soil properties can be affected by grazing animals. On the negative side, animals can compact the soil. However, through applying nutrients as dung and urine, they help the surface soil to contain active micro-organisms and plants which in turn help soil structure. Also some grazing increases net plant growth from a pasture and so animals can increase overall production. The nutrient capital of a soil greatly affects the productivity and persistence of plants growing on that land.

Microbial activity is crucial for healthy soil processes. These depend particularly on labile soil carbon (i.e. the fraction which is readily broken down by microbial action – not lignified tissue) being available as an energy substrate for microbial function. Microbial organisms turn over nutrients and exude polysaccharides which help ‘glue’ soil particles together, giving soil its structure.

Pasture sustainability
Ideally, we want pastures to last for decades without a need to re-plant them. This means that management of pastures over the long term is crucial. Keeping a desirable pasture composition will greatly assist a farmer to remain financially viable and minimise problems such as weeds, vegetable fault, etc. Pastures can last for decades provided that management (i.e. grazing management and maintenance of adequate nutrition) is good.

The crucial elements for productive animal enterprises are the quantity and quality of the feed available. Managing for high levels of green, digestible leaf is an important objective. Animal production is driven by the availability of green digestible leaf.

Animal sustainability
Weight losses need to be avoided - both for animal welfare and for production aims. Reproductive performance is also dependent on good nutrition. Good pastures also help animals resist internal parasites. Animal productivity depends largely on the feed available. Quality products (tender meat and fine wool with sufficient strength) are increasingly being sought to satisfy demanding markets. In future, desired growth rates will need to be attained from pastures if graziers are to get top prices for their products. As meat, milk and wool are all protein-rich products, we need pastures that supply sufficient energy and protein – hence the need for high protein (highly digestible) pastures.

Is biodiversity important in grazed pastures?
The term ‘Biodiversity’ is commonly used to refer only to native plant species. We contend that it should include all plant species and associated biota. A clear link has not been reported between plant biodiversity and livestock productivity. The major published claims for biodiversity function are based on undisturbed communities - not grazed pastures. Biodiversity may not be important for productive livestock enterprises.

That is not to say that biodiversity per se is not important from the point of view of preservation of diversity in natural ecosystems. But pastures managed for livestock production are not intended to be suited to the preservation of rare and endangered species. Even though they may not be ‘biodiverse’, there are examples of sown perennial pastures that are still productive some 80 years after being sown.
It is difficult to manage pastures to retain a suitable balance between 2 or 4 species, let alone attempt to manage for 40 species. In productive livestock systems, we need as many of the plants producing digestible green leaf as possible, hence the need for relatively simple and manageable botanical compositions.

In the recent Sustainable Grazing Systems Key Program, herbage accumulation was less and growth more variable in pastures high in biodiversity.

In a paper summarising the biodiversity theme across this research program, Kemp et al (2003) stated:

> Across sites there was a small tendency for net annual herbage accumulation to be less on the more diverse treatments (see Figure 4.22 below) as indicated in the regression modelling …. No site showed any apparent increase in species number with increasing productivity”.

That is, the highest annual growth was observed in pastures comprising about 10 species while annual growth tended to decline as the number of plant species increased to 40 or more (Figure 4.22).

**Figure 4.22** Mean relationship between total species richness (ie biodiversity) and total annual herbage accumulation in grazed pastures across 6 sites. Source: Kemp et al (2003).

Are fertiliser inputs really necessary in sustainable systems?

There is ample evidence that low fertility constrains the productivity of Australia’s pastures – remember that Australia’s soils are some of the oldest and most leached in the world. Fertiliser inputs are therefore necessary to relieve this constraint. There is a commonly held perception that fertilisers cause soil acidity. We know that acidity is linked largely to leaching events (especially of nitrate) and is a common natural occurrence. We can manage our soils to minimise leaching of nitrate and thereby minimise soil acidification. Remember also that product removal means nutrient depletion. We cannot have sustainable systems if nutrients are not replenished. We can get N and C fixed from the atmosphere but P, K and S exported from the system have to be replenished by using fertilisers.
We need to recognise the nutrient cycles which flow from the soil to the plant to the animal and then, through dung and urine, back to the soil again.

Figure 4.23 was constructed based on 4 experiments conducted in different regions across Australia to explore the interaction between fertiliser inputs and stocking rate on wool production. We propose that the data suggest a region of sustainability shown as the optimum range below.

**Figure 4.23 Combined data from 4 experiments across southern Australia suggesting an optimum balance between fertiliser inputs and stocking rate.**  
**Source:** Scott et al. (2000).

The combined data suggest a boundary region defining sustainable grazing systems. This boundary region is associated with:

- sufficient nutrients
- little supplementary feeding
- little loss of desirable plants and
- utilisation of feed grown using sufficient stock.

### 4.10 Review Questions

- You are establishing a new improved pasture for sheep - outline your management of the pasture over the first 5 years.
- Explain how you would determine how to graze a native pasture on the Northern Tablelands
- For a familiar property outline how you would decide which paddocks to treat for weeds and/or lock up for conservation
- How would you measure the sustainability of a grazing enterprise?
- Give an overview of objective evidence that supports cell grazing
- Describe the interaction between fertiliser, stocking rate and grazing management in determining the profitability of a sheep grazing enterprise
4.11 Readings

Chapters 14 and 18 of the International Sheep and Wool Handbook cover sheep feeding and pasture management.

Making More Money From Sheep: Module 7 Grow More Pasture

Optional readings


Saltdeck: Species for saline soils.


4.11 References


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## Glossary of terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell grazing</td>
<td>Grazing animals within a &quot;cell&quot; consisting of a large number of paddocks of a size which permits a high stocking density to be applied to each paddock for a suitably short period. Grazing and rest periods are determined according to available herbage and estimated rate of recovery of desired pasture species</td>
</tr>
<tr>
<td>Continuous grazing</td>
<td>Similar to set stocking but it is a less confused term describing a more common situation</td>
</tr>
<tr>
<td>Dry sheep equivalent (dse)</td>
<td>The dry sheep equivalent of a livestock class is defined in the PROGRAZE manual as the feed requirement of that livestock class relative to the feed requirement of a two-year old 50 kg Merino wether</td>
</tr>
<tr>
<td>Intensive rotational grazing</td>
<td>Stock moved to a fresh pasture regularly (up to twice a day). The pasture rest period is long compared to the grazing period</td>
</tr>
<tr>
<td>Leaf area index (LAI)</td>
<td>The ratio of the sum of the area of all the plant leaves divided by the surface area of the ground on which those plants are growing. A dense pasture can have a LAI of 5 or more</td>
</tr>
<tr>
<td>Rotational grazing</td>
<td>Rotating stock around a number of paddocks. Movement can be based on fixed time period, plant regrowth or animal intake</td>
</tr>
<tr>
<td>Rotational grazing types: Time (calendar) based</td>
<td>Uses fixed time intervals for stock movement</td>
</tr>
<tr>
<td>Rotational grazing types: Pasture growth based</td>
<td>Aims to keep pastures in their most active growth stage (represented by feed-on-offer [kg DM/ha], pasture re-growth phase or leaf stage)</td>
</tr>
<tr>
<td>Rotational grazing types: Animal intake based</td>
<td>Provides a calculated amount of feed per animal per day</td>
</tr>
<tr>
<td>Set stocking</td>
<td>Animals grazing a paddock for an extended period, at the most extreme, for the full year. Animals are usually only moved for husbandry activities or if paddock feed runs out. In practice it is an ambiguous term with a range of meanings and we recommend that the term be no longer used (see Continuous grazing)</td>
</tr>
<tr>
<td>Stock density</td>
<td>The number of dry sheep equivalents/ha in a paddock at any one instant</td>
</tr>
<tr>
<td>Stocking rate</td>
<td>The total number of dry sheep equivalents/ha on a farm/paddock averaged over a calendar year = total dses carried over the year/area/365</td>
</tr>
</tbody>
</table>