Plant / climate interactions

Plant growth is the result of genetic factors acting in concert with the environment. The genetic factors control a plant's physiological and morphological characteristics, which in turn determine the plant's response to growth conditions. This is also the basis by which plants ***adapt*** to changes in their environment.

The environment for plant growth in pastures is highly variable in space and time, and often stressful. To grow and manage pastures successfully, we must understand how plants cope with environmental variation and stress. This tutorial considers the mechanisms by which plants adapt to their climatic environment, and what this means for the choice of species to use in pastures for different situations.

Themeda triandra **(kangaroo grass) growing on a roadside in western Victoria. Native species like kangaroo grass evolved in the Australian landscape and are highly adapted to the stresses imposed by soil and climate.**

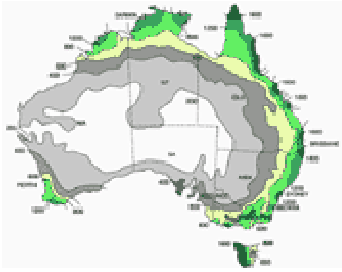
This steep hillside contains dozens of microhabitats, each presenting different growth conditions for pasture plants.

Of all the factors that can influence the growth and composition of pastures in Australia, climate has the greatest effect. Unlike other factors that can influence pasture growth such as soil fertility, we have little control over the climate. Therefore, it is critical to choose species that are adapted to the climate of the site when designing pasture mixtures, since mistakes at this level cannot generally be corrected by changing management inputs.

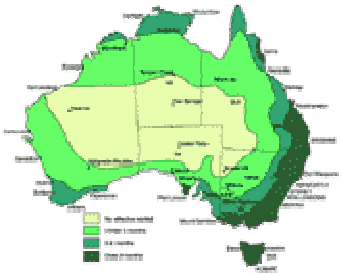
The key climatic factors are rainfall and temperature, because they generally limit plant growth for some part of the year in most areas. Rainfall provides the water for plant growth (this is supplemented by irrigation in some situations). Temperature controls the rate at which the biochemical processes of plant growth proceed. Of these two potential limiting factors, rainfall is the dominant one.

Solar radiation, the primary source of energy for photosynthesis and plant production, does not usually directly limit pasture growth in Australia. Therefore, in this tutorial we will concentrate on rainfall and temperature, and plant adaptation to these factors.

Australia is a dry continent. Almost 80% of the land mass has a mean rainfall of less than 600 mm per year, and half of the continent has a mean rainfall of less than 300 mm per year. Temperatures range from cool-temperate in the south, to hot and humid in the tropical regions of the far north. Rainfall and temperature vary greatly across Australia.



Median annual rainfall.



Effective rainfall in Australia. Effective rainfall is defined as the number of consecutive months per year when rainfall exceeds 33% of potential evaporation.

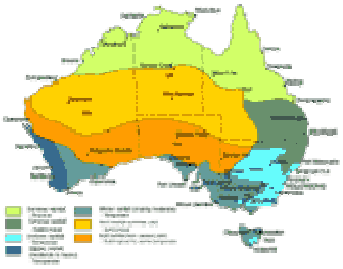
You can see a larger version of these maps by in the 'Maps' section on LMS.

A combination of low rainfall and high temperatures (leading to high potential evapotranspiration rates) means that the length of the growing season is restricted throughout most of the country, sometimes severely. Only the eastern seaboard has an effective rainfall period (the number of months where mean rainfall exceeds one third of mean evapotranspiration) of greater than 9 months.

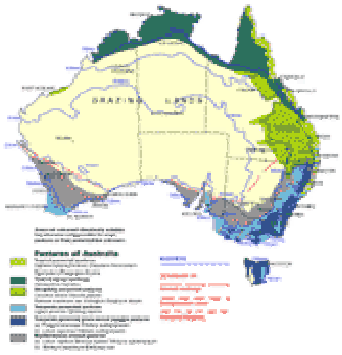
Based on rainfall patterns and mean January and July temperatures, Australia can be divided into seven distinct climatic zones. The environment for plant growth in each of these zones is quite different, and therefore the pastures found in each zone also differ markedly.

How does this variation in macroclimate influence the types of pastures found throughout Australia?

There are 6 major pasture zones recognised in Australia. Click on the map below to see a larger version. These range from high rainfall tropical zones along the Queensland coast to dry, Mediterranean-type zones across parts of southern Australia. While the 6 zones do not exactly match the climate zones described in the previous screens, they nonetheless reflect the prevailing influence of climate. Note, for example, how the pasture zone boundaries tend to follow the rainfall isohyets on the map.



Climatic zones of Australia.

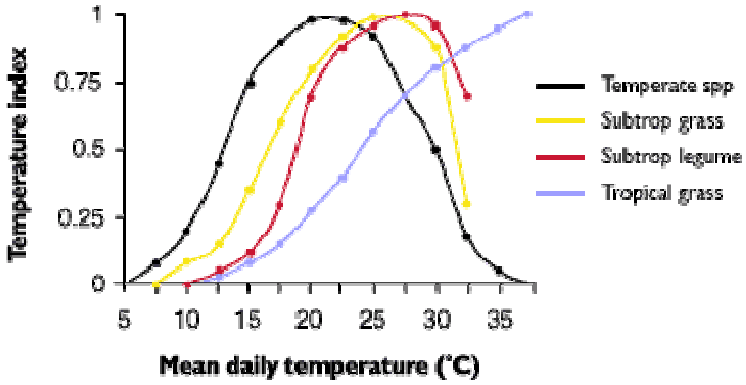


Pastures of Australia.

This macro-scale description provides some good illustrations of the adaptive features of pasture plants that lead to the emergence of distinct pasture zones.

For example, in the north of the country, the high temperatures favour grass species with the C4 photosynthetic pathway compared to species with the C3 photosynthetic pathway. The C3 pathway includes the process of photorespiration (release of CO2 in light), which uses energy that would otherwise be available for new growth. C4 plants do not incur this cost and photosynthesis does not become light-saturated at high light intensities as it does in C3 species. C4 plants can also continue photosynthesis when the concentration of CO2 in their leaves is very low (for example when the stomata are nearly closed). For these reasons, C4 plants have an advantage, compared to C3 plants, at high temperatures and during times of moisture stress.

In general, the tropical and sub-tropical grasses, with their more-efficient photosynthetic pathway, reach their maximum growth rates at higher temperatures than the temperate (C3) grasses. The graph below illustrates this, using the idea of a 'temperature index'. A temperature index value of 1 means that plant growth rate is at its maximum at this point, which is usually considered to equate to the 'optimum' temperature for growth. The graph shows the optimum for temperate species occurring at around 20 degrees, whereas for the subtropical grasses the optimum is around 26 degrees and for tropical species it is over 30 degrees.



Pastures at lower latitudes are dominated by C_3 species. C_4 plants are very sensitive to cold temperatures. The transport of photoassimilates in C_4 species is inhibited below about 7-8 degrees C. In contrast, temperate grasses like perennial ryegrass can grow actively throughout winter and down to temperatures below 5 degrees C.

However, this does not mean that C_4 species are unable to grow at cooler temperatures. Some C_4 plants are often present in pastures in the temperate zones, but their growth period is restricted by the onset of colder conditions, particularly the timing of the first frosts which usually curtail their growth.

Nor does it mean that C_3 grasses are unable to grow at higher latitudes. Some, like perennial ryegrass, are used in northern New South Wales and southern Queensland. However, they are

susceptible to hot conditions, particularly when night temperatures are also high because this leads to increased rates of dark respiration and energy consumption. Similar problems occur in summer in the irrigation area of southern NSW and northern Victoria. Pastures based on perennial ryegrass are often short-lived (2-3 years) in these areas. Other species like tall fescue and prairie grass are generally more tolerant of hot conditions. This difference in environmental tolerances reflects the origins of the species. Perennial ryegrass originates from cool-temperate regions of Europe, whereas tall fescue originates from the hotter, drier climates of North Africa / southern Europe, and prairie grass is originally from South America.

This is a good example of the effect of ***temperature*** on the potential use of pasture species in Australia.

There are also some good examples of how plants adapt to limited moisture availability in this macro-level description of pastures zones. One example is how the perennial grass species present in the temperate perennial pasture zone (perennial ryegrass) differs from the temperate perennial grass - annual legume zone (phalaris, cocksfoot and tall fescue).

Species like phalaris characteristically enter a state of dormancy when conditions become dry at the end of spring. New growth slows or ceases altogether, and vegetative buds are formed at the base of old flowering stems. These buds develop into new season tillers in the following year with the arrival of autumn rain and / or cooler temperatures. In this way, the plant limits its requirements for water at a time when water is not readily available in the environment.

A flowering stem of phalaris. The buds are red in colour and three of them are visible at the base of the stem.

In contrast, perennial ryegrass continues to produce new growth during summer if, for example, summer showers supply some moisture. However, it is ill-equipped to maintain water uptake because it has a relatively shallow root system (50 - 60 cm depth, compared to phalaris which can produce roots at depths greater than 1.5 m) and cannot access sub-soil moisture.

This is a good example of the effects of ***rainfall***, or soil moisture availability, on the potential use of pasture species in Australia.

Cross-section of the soil surface under a ryegrass / white clover pasture. Most of the plant roots will be found in this depth of soil (about 8 cm).

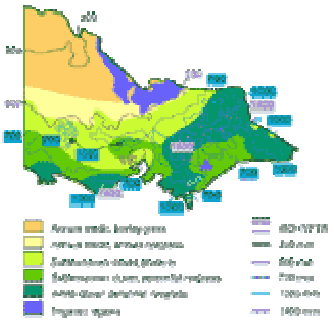
Another example of the effect of soil moisture availability is seen in the distribution of species with perennial and annual growth habits.

In regions with dry summers, annual species effectively avoid the effects of summer moisture stress by producing seed in spring, after which vegetative growth ceases. The plant population re-establishes in the following year after autumn rains stimulate the germination of seed (see the diagram below).

The effect of this adaptive feature is seen most clearly in south-eastern Australia, where there is a gradient in pasture types as the average rainfall decreases moving inland.

In contrast to southern Australia with its dominance of winter/spring rainfall, the sub-tropical and tropical regions in the north receive most of their rainfall in summer. Here, the annual growth habit can also help plants tolerate moisture stress. The difference is that these species are *summer* annuals (that is, they germinate with the arrival of spring / summer rain and set seed before the arrival of dry conditions in winter, eg Townsville stylo (*Stylosanthes humilis*)) as opposed to the *winter* annuals that grow in the temperate regions (eg sub clover, *Trifolium subterraneum*).

Victoria too has several distinct pasture zones. These zones also reflect the influence of climate, particularly the distribution of rainfall. Note how the boundary of the pasture zones follows the average rainfall isohyets.



Pasture Zones of Victoria

These zones are an important guide to the choice of species for pastures in the State. They also reflect the potential productivity of pastures, since productivity is closely related to average annual rainfall.

The graph below shows the relationship between average annual rainfall and stocking rate achieved, for 'Control' (low fertiliser input) and 'Productivity' (high fertiliser input) paddocks in the Grassland Productivity Program which ran in south eastern Australia from 1993 - 1997. The dotted line indicates that, for every 25 mm of average annual rainfall above 250 mm, an additional 0.8 dry sheep equivalents can be carried per hectare on pastures receiving low inputs of fertiliser. The increase is even steeper, about 1.3 additional dse / ha for every additional 25 mm rainfall, for pastures receiving higher fertiliser inputs. This increase in carrying capacity reflects the increase in pasture growth, usually over a longer growing season, that results from higher rainfall.

Predicted potential carrying capacity (DSE/ha) according to the length of the growing season and average annual rainfall.

	Rainfall (mm)			
Season (months)	500	700	900	1100
5	12	14		
7		19	21	
9		24	26	28
11			31	33

Conclusion

Climatic conditions, especially rainfall and temperature, are arguably the most important factors governing the potential use and productivity of pasture species. It is possible to identify distinct pasture zones in Australia and in Victoria, in which certain pasture species and types perform well. These zones are a useful first 'screen' to apply when deciding on pasture mixtures for a given region.

The adaptability of species to different climatic conditions depends on their ability to cope with the prevailing stresses, such as low water availability, or high temepratures. In turn, the adaptive ability of species is a function of their origins because, over evolutionary time scales, traits that favour plant survival have been selected in locally-adapted material. In Australia, we are dependent largely on plant material that originated overseas for our pastures. Hence we must understand and measure the adaptive range of those species in order to be able to use them successfully.