SECTION B:

Pastures and soil organic carbon

1. Role of pastures in Australian farming systems

The primary purpose of growing pastures is to supply feed for livestock for meat and wool production. However, in Australia, pastures also play an important role in improving soil chemical, physical and biological properties of soils used for cropping.

Figure 11. Mixed farming of pasture/crop rotation is common in Australia.

In traditional pasture/crop systems, SOC declines under cropping but increases under pasture phase (Figure 12).

Pastures are grown alternately with crops to:

- replenish soil organic matter and plant nutrients
- manage disease
- increase water holding capacity
- improve water infiltration and drainage
- enhance biodiversity
- provide enterprise diversity

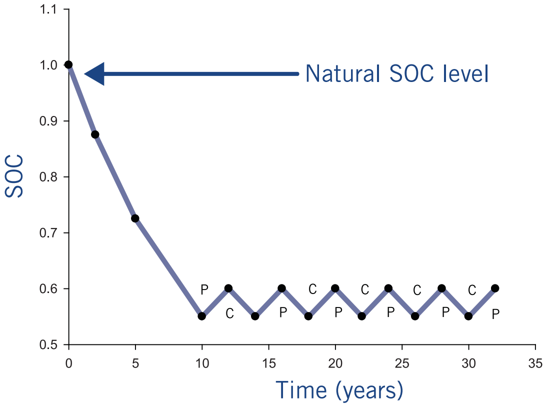

Figure 12. An example of soil organic carbon levels under pasture (P) and crops (C) rotation.

The pasture phase therefore plays the vital role of maintaining long term SOC and the long term fertility status of agricultural soils in Australia. However, this cyclic fluctuation may be at values well below the local carbon sequestration potential as indicated by the natural SOC level in Figure 12.

Reasons for higher SOC under pasture

Soils under pastures tend to have higher SOC than cropped soils because they:

- have a higher root to shoot ratio than many crops
- are not disturbed
- have lower rates of decomposition.

Higher root to shoot ratio

The root to shoot ratio (R/S) is the ratio of the plant's root biomass (below ground) to its shoot biomass (above ground).

The R/S range in temperate grasses is between 0.4-3.7.

The R/S in crops can be as low as 0.1.

Perennial pastures usually have higher R/S than annual pastures. For example, the R/S of phalaris is 1.0; the R/S of subclover is 0.45.

Minimal soil disturbance

When soils are undisturbed, SOC is able to reach an equilibrium level. Disturbing soils with tillage is the main cause of SOC loss in agricultural soils. Turning over the soil exposes SOC to air and microbial attack, resulting in increased decomposition rates.

Lower decomposition rate

As discussed earlier, soil moisture content affects the rate of SOC decomposition. Since soils under pasture are usually drier than cropping soils, especially when the latter are under fallow, SOC in pasture soils generally decomposes more slowly compared with cropping soils.

Therefore, SOC is higher under pastures than under cropping and the difference becomes larger as the rainfall increases (Figure 13).

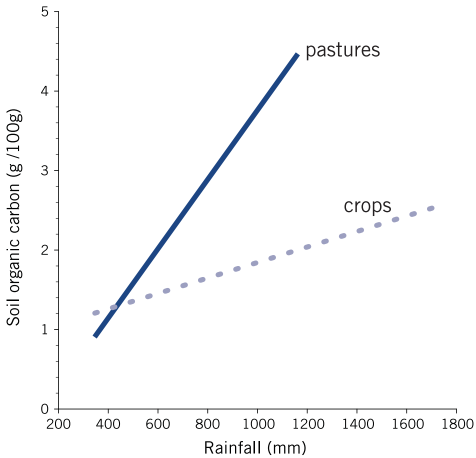

Figure 13. SOC levels in pasture soils compared with cropping soils (0-10 cm) as a function of rainfall in NSW (Gibson et al. 2003).

2. Pasture types

Annual pastures

In Australia, annual pastures are often used in the pasture phase in ley farming systems. The ideal annual pasture should have more than 40% legumes to provide protein and energy rich feed for ruminants and to fix nitrogen in the soil for following crops and grasses. A well managed legume-based pasture can potentially accumulate large amounts of nitrogen (30-200 kg N/ha annually) with the potential to substantially improve crop yields in the short term. In much of southern Australia's acid soil country, subterranean clover is the major species used in short term rotations. Use of annual legume-pastures may accelerate soil acidification if the soil nitrate nitrogen is leached below the root zone.

Perennial pastures

Perennial pastures (e.g. Phalaris, Figure 14) are less acidifying than annual pastures because there is less nitrate leaching. Their long-lived deep root systems take up soil water more effectively than annual pastures reducing soil acidification and the risk of dryland salinity. They use soil water from the deeper part of the soil profile and can respond quickly to out of season rainfall such as summer storms. They may not produce more biomass than equally well managed annual pastures but the seasonal production of that material may better meet the needs of the livestock grazing them.

There is currently little data available on the carbon sequestration potential of annual and perennial pastures. We do know that annual pastures return all of their shoot and root biomass to the soil every year when they die, and that carbon stored in perennial root systems deep in the soil is less easily decomposed than soil carbon close to the surface. However we do not have enough information about the relative effectiveness of the two pasture types in sequestering SOC.

Figure 14. Phalaris provides the perennial component to the perennial pasture (above left). Both pastures contain annual species such as subterranean clover, annual ryegrass, barley grass and silver grass.

Native pastures

Soil beneath undisturbed native pastures (Figure 15) is sometimes used as a benchmark for natural SOC levels, but these pastures may not provide the best estimate of a district's soil carbon sequestration potential, particularly if the native system is deficient in essential plant nutrients. Unimproved native pasture has the potential for increases in SOC for many years if improved pasture management practices are used. A small increase of SOC per hectare on these unimproved pastures would result in considerable SOC sequestration given the large areas of unimproved native pasture in NSW. Improved pastures generally have higher ability to sequester more carbon in the soil than unimproved native pastures because of their higher productivity. These improved pastures will include legumes such as subterranean clover but the grass component may be exotic species such as phalaris and ryegrass or native species such as danthonia and microlaena. Fertilisers, (usually P fertilisers) are often needed to increase pasture production. However, if fertiliser is added to increase carbon sequestration under pastures, it must be continued regularly to maintain the higher level of forage production. Without these continual inputs, the sequestered soil carbon will eventually be lost.

Figure 15. Both pastures contain microlaena and danthonia but the improved pasture (above left) has a strong legume component which boosts its productivity. Note the exposed bare soil in the native pasture (above right).

3. Overgrazing

Historically, overgrazing has been a major cause of widespread land degradation in Australia, and on occasion has contributed to the collapse of livestock industries.

Overgrazing can seriously damage the pasture sward and the soil beneath it. Desirable species can be grazed out and replaced by less desirable weeds. Frequently these weeds species are not only less productive but provide less protection to the top soil. For example, cape-weed rapidly decomposes at the end of spring leaving the soil exposed to erosion.

Overgrazing occurs when the stocking rate is higher than the pasture base can withstand. It may occur in continuous grazing systems such as set-stocked grazing where there is less opportunity for pastures to rest and recover after grazing. This is the traditional grazing management practice in Australia.

Heavy-hooved animal traffic on wet soil can be worse than tillage, not only disturbing and exposing the soil but also causing serious compaction problems. Cattle and sheep are especially hard on soil. Intensively trafficked areas often become bare and are sources of soil erosion, leading to significant losses of topsoil, nutrients and organic matter, while the less obvious soil compaction of larger areas can reduce the productive capacity of the pasture system.

Overgrazed pasture not only cannot sequester much soil carbon but is vulnerable to losses due to erosion (Figure 16). It is therefore important to maintain adequate ground cover to protect the soil surface from wind and water erosion.

Figure 16. Overgrazed pasture with exposed soil surface (Photo: I Packer).

4. Rotational grazing

Rotational grazing systems have a large number of animals graze a limited area for a short time, after which the paddock is rested for several weeks or months before the animals return.

These systems increase competition between animals for forage and force them to consume plants that they would otherwise ignore. In addition, rotational grazing can be used to manage the height of pasture to optimise both pasture and livestock production and to rest pastures at times critical for plant reproduction or persistence. During the resting period, both the soil and pasture have time to recover from grazing disturbance. This can be used to foster the persistence of desirable and more productive species. Overall, rotationally grazed systems have the potential to increase pasture biomass production over time and so ultimately lead to higher soil carbon levels. However, little information is available on the magnitude of the SOC increase, if any, due to this improved management practice. Promoters of rotational grazing assert that the additional costs and management issues with rotational grazing are outweighed by the benefits of the system.

Figure 17. Rotational grazing: showing a flock of approximately 2000 sheep left on the paddock for short periods of time during the year. The paddock is rested for the remainder of the year allowing pasture growth, suppression of weeds and general repair of soil structure (Photo: I Packer).

5. Pasture cropping

Pasture cropping refers to an intercropping technique first developed in the central west of New South Wales and involves the direct drilling of winter-growing cereals into the predominantly summer-growing native perennial pastures.

From the perspective of soil carbon sequestration, the system may have the potential to increase SOC. There is less soil disturbance in the cropping phase compared with full cultivation, so lower SOC losses. Where pasture cropping successfully re-colonises run-down pastures or cropped soils with well-adapted native pastures, the role of pastures in sequestering soil carbon may be restored or enhanced.

However, while there have been claims that soil organic carbon under pasture cropping should be higher than of that under pasture of conventional ley/crop systems, there is little scientific data currently available.

Figure 18. Pasture cropping: sowing of oats into a winter dormant pasture of red grass (Bothriochloa macra) in central west NSW.