Introduction

Has your interest in planting trees been triggered by a soil problem? Trees can help conserve soil on your land by:

- reducing soil erosion;
- increasing soil organic matter;
- improving soil structure; and
- assisting in nutrient cycling.

Soil salinity and waterlogging can also be ameliorated by trees and are covered in greater detail in the salinity section of this manual.

The purpose of using trees for soil conservation is to assist in retaining fertile soil on the farm where you need it most by regulating flows of wind and water.
Soil erosion – what happens when soil goes?

The top few centimetres of soil are critical to crop and pasture growth. This is because topsoil is usually the most fertile portion of the soil profile, and any loss of it will therefore result in a loss of soil fertility. While the loss of a few millimetres of soil may not seem critical in any one year, over several years these losses will cause decreased crop and pasture growth and lead to an increase in fertiliser requirements.

Soil erosion can take many forms, including gully, rill, wind, sheet and water erosion. In general, soil erosion occurs because of:

• over-clearing of the land;
• over-grazing;
• strong winds; and
• rain.

Where do I start?

It is often wise to begin soil conservation work at the head of the catchment because your gains here will benefit land lower in the catchment. A catchment is any area of land that catches and drains all the rain which falls on it. Therefore, a slope which supplies water to an erosion gully is a catchment, as is the Murray-Darling basin (Figure 11).

Your property may have several catchments on it and you can manage their water flows. However, your property will also lie within a larger catchment and it will be most effective if you manage this in cooperation with other landholders.

By managing water flow you are able to slow the rate at which top soil moves out of the catchment and thus you can retain the most fertile part of your soil.

Using trees to conserve soil

Trees can help reduce erosion by:

• slowing wind and water flows;
• providing protection from wind and water;
• holding soil together; and
• increasing infiltration.

The first step in combating erosion is to identify the type of erosion that occurs on your property. Having done this, by choosing the right type and placement of trees you will be able to take steps to overcome the problem.

Gully erosion

Gully erosion occurs when:

• the shape of the terrain concentrates water flow over or through the land; and
• the soil is not cohesive enough to prevent soil loss.

Gully erosion is best controlled by reducing water flow to it rather than by trying to stop erosion in the gully. However, you can have a significant impact by taking steps on your own farm even if you are unable to convince everyone in the catchment to become involved in fixing the problem.
Slow down the rate of water flow. This can be done by planting trees on higher ground around the gully area. Wherever possible, trees should be planted in conjunction with deep-rooted and fast-growing grasses which will also use water, increase infiltration and control flow. While slowing of water flow may not prevent gully erosion completely, it can dramatically reduce the rate of erosion. Diversion banks can take water elsewhere, but quite often this just shifts the problem to a new site. Building a dam is an effective but expensive solution.

Trees can help hold the soil together. Although not as important as reducing flow, trees planted in and around the gully may help hold the soil together. The closer you are to the gully, the wetter the soil will be, and you may want to plant different tree species.

To avoid scouring, plant small shrubs with flexible stems within the gully rather than trees.

Sheet and rill erosion
Sheet and rill erosion are caused by:
• slope length and steepness;
• poor ground cover and surface roughness;
• poor tree and shrub cover;
• poor soil structure;
• poor infiltration; and
• intensity of rainfall.

If your property suffers from sheet or rill erosion you will again need to slow down the rate of water flow, increase infiltration, and keep as much ground cover on the soil surface as possible.

Slow down the rate of water flow. Both the length and steepness of the slope have an impact on the rate of water flow. The rate of soil loss increases with the length of the slope.

Slope length can be decreased by planting trees across the slope.

The distance between the rows of trees planted across the slope affects slope length which in turn affects the rate of soil loss. Trees and shrubs can also be planted in strips along contours to check run-off.

Banks can be used to decrease slope length, but trees are much less susceptible to damage by floods than conventional banks and have the added bonus of increasing the rate of water infiltration. Where banks are being used, trees can also be planted on them to provide bank stabilisation.

The effect of slope angle on soil loss is shown in Figure 13. The steeper the slope the faster water flows and the greater the chances of soil erosion. While trees obviously cannot change slope steepness, they will slow down the rate of water flow when planted across the slope.

Trees are most effective on steep slopes when used in conjunction with dams and contour and diversion banks for changing slope angles and increasing infiltration.
**DESIGN PRINCIPLES FOR FARM FORESTRY**

**Trees for soil conservation**

Increases in soil organic matter and litter from trees and other vegetation help improve soil structure and increase infiltration. The better the soil structure the more spaces there are for soil infiltration and storage. Similarly, the more soil organic matter the greater the activity of soil organisms and the more channels they make for water entry and storage. All vegetation forms root channels which promote the entry of water. The more water that enters the land the less there is to run-off and carry soil away.

**HINT**

The rougher the ground the slower water will flow

Leaving tree stumps and stones in place will slow water flow. The occurrence of tree trunks, grass tussocks, logs or other obstructions and the lying of branches on the contour are also ways of decreasing water flow.

Because tree roots are able to penetrate compact soils they can be particularly effective in increasing water infiltration in areas of high soil compaction. Although it may take many years before you get to see the benefit of the ‘biopores’ (continuous pores left behind after roots have decayed) made by tree roots, these pores are very important. Even我们的 annual crops today often get through compacted subsoils by using biopores made by trees many years ago before the land was cleared.

When planting trees to overcome soil compaction/water infiltration problems, choose species carefully as not all trees are suitable for planting on compact soils.

**Increase surface roughness.** The rougher the soil surface the slower the rate of flow, the greater the infiltration and the less the soil loss. Roughness is enhanced by vegetation (live and dead), including stumps, fallen branches and litter. To rehabilitate land you can cut and arrange branches along the contour where they trap litter and seeds. As the seeds germinate and grow, these areas become little fertile strips which increase their control over water and wind flow and nutrient cycling over time.

**Protect the soil from heavy rainfall.** Choosing trees which allow grasses to grow under them so that water infiltration is increased and the soil is not left bare will help protect the soil from rain (Figure 14).

Ground cover varies during the life of an agroforestry crop. It is lowest at times of establishment, when bare land is highly vulnerable to erosion.

**Mulching or planting cover crops can help overcome bare soil at tree establishment.**

Plantations are vulnerable to erosion again at harvesting. Even a single storm can wipe out years of benefits which accumulated while the trees were growing.
Slumping
Slumping of hillsides occurs when:
• slopes are steep;
• rainfall is heavy;
• soils are deep;
• infiltration is good until the land is saturated;
• evapotranspiration is slow;
• the underlying rock is parallel to the slope; or
• the rock has a low-friction surface (eg shale).
Trees are often the most effective option on land prone to slumping. Because slumps are generally high on the slope dams may not be feasible. Because infiltration is generally good on slump-prone areas, trees which bind and dry the soil reduce the risk of slumping. Diversion banks might also be of assistance.

If you are in an area of high rainfall and have soils prone to slumping choose tree species which are deep-rooted and which have high water use.

Wind erosion
Wind erosion occurs when the force of wind is sufficient to detach and carry soil particles. The factors that affect the rate of erosion by wind are:
• soil type;
• ground cover;
• shelter; and
• windspeed.

The higher the proportion of fine sands and the drier the soil, the greater the susceptibility to wind erosion because these particles are small enough to be carried and are not cohesive. Soils with the least ground cover are obviously the most prone to erosion, while the more elevated parts of the landscape tend to receive the highest wind speeds and so are also very susceptible.

Trees can provide shelter against prevailing winds and thus decrease wind speed. The role of trees in providing shelter is covered extensively in the chapter on trees for shelter and shade, so only the basics as they relate to soil loss will be covered here.

If wind erosion is already a serious problem on your farm, choose fast-growing tree species when planting windbreaks.

Trees are most effective at decreasing soil erosion when planted at 90 degrees to the prevailing wind. Figures 15 and 16 show the effect of planting windbreaks at 45 degrees and 90 degrees to the prevailing winds.
Trees for soil conservation

Figure 15: Wind blowing 90° to windbreak (distance from the windbreak in multiples of windbreak height (H)).

Figure 16: Wind blowing 45° to windbreak (distance from the windbreak in multiples of windbreak height (H)).

Both figures adapted from Leys (1991).
Areas prone to wind erosion are coastal sand dunes and inland rainfed farming areas where soils are sandy and mean annual rainfall is less than 400 mm per year. Much of Australia’s wheat is grown on such land. Alley farming, which involves planting rows of trees to form ‘alleys’ between rows of crops or pastures, may be suitable in these conditions. Often the trees are planted at approximately 90° to the prevailing wind to form a permeable barrier. The spacing and height of the rows of trees help determine the amount of shelter which they provide for the crop or pasture in between.

**As a rough guide, if windbreaks are 2 metres high, row spacing should be 25 m.**

This spacing can of course be adjusted to fit your machinery and particular wind conditions. Usually, alley farming trees are used for grazing (see chapter on trees and shrubs for fodder), although prunings from the trees can also be used to supplement ground cover.

### Soil organic matter and nutrient recycling

Trees recycle nutrients by taking them up from depth and depositing them on the soil surface as litter, which then decomposes to form soil organic matter. Because they are deposited under the trees, the challenge is how to make these nutrients available to crops and animals. Options are to:

- alternate tree and annual crops or pasture on the same land in a long rotation;
- grow fodder trees and let animals transport the nutrients;
- grow fodder trees and transport the fodder to the animals; and
- grow crop or pasture alongside the trees, and place prunings on the crop (eg alley farming).

The design of layouts to enhance the benefits of trees on crops and pastures is discussed in the chapter ‘Capturing multiple benefits’.

### Organic matter

Organic matter improves soil nutrient content and structure. The amount of organic matter contributed by trees is affected by:

- the volume of foliage dropped;
- the quality of foliage dropped;
- additions from the roots; and
- tree species.

The rate at which litter decomposes to organic matter is affected by the ratio of carbon to nitrogen in the soil. Usually, the higher the level of nitrogen in the leaves the greater the contribution of litter to organic matter. Digging the litter in increases the rate of decomposition. Tree litter low in nitrogen may immobilise fertiliser. Nitrogen from foliage is much less prone to leaching than that from commercial fertilisers.

**Trees vary greatly in the type, volume and effectiveness of nutrients they recycle.**

### Nutrient cycling

Leguminous trees usually add more nitrogen to your soil than other tree types, while other tree leaves are low in nitrogen and may immobilise fertiliser. Some native acacias seem to produce litter which decomposes very slowly. The actual amount of nitrogen added depends on tree species and local conditions.

Some trees (eg *Banksia* species, *Eucalyptus gummifera*), increase the availability of phosphorus by secreting root exudates. Others grow in association with mycorrhizae, which also increase the availability of nutrients (eg *Pinus radiata*, *Eucalyptus marginata*). Establishment of such plants can be a step in the rehabilitation of degraded land.
**Trees for soil conservation**

Nutrient recycling of trees on crop and pasture growth can be most effective when trees are planted in alley farming systems. Tree canopies can trap significant amounts of nutrients, a source of free fertilizer which is washed from the leaves to your soil by rain.

Examples of nutrient additions and recycling from trees are in the Table 1.

### Thinning and harvesting

If trees are thinned or harvested as timber, nutrients will be exported, though usually less than are lost through cereal cropping.

**Nutrient losses are reduced by leaving roots, foliage and bark on site, and minimising soil disturbance.**

In the majority of cases, commercial tree harvesting leaves trees residue on site, thus reducing fertiliser requirements for the next tree crop. As with all other crops, soil testing will help determine fertility losses.

### Time-scale

We have seen that trees can control landscape processes, but they do this on a longer time-scale than pastures and crops. For example, trees can improve soil fertility at a site, but the improved patch remains under the tree until it dies or is removed. If it suits your farming objectives, you could alternate trees and crops on a long cycle (10 years or more) as a way of using the improved fertility.

### Table 1: Nutrient additions from trees

<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>Nitrogen yield, kg/ha/yr</th>
<th>Phosphorus yield, kg/ha/yr</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinus radiata plantation</td>
<td>14–24</td>
<td>0.97–2.30</td>
<td>Gippsland</td>
</tr>
<tr>
<td>Eucalyptus forest</td>
<td>21–46</td>
<td>0.94–2.00</td>
<td>Gippsland</td>
</tr>
</tbody>
</table>

**Reference / Further reading**


When planting trees for the purpose of soil conservation, the investment is being made primarily to ensure the long term viability of the farm rather than for the direct value of the trees. Native species may be used which will offer a good opportunity to capture nature conservation and scenic beauty objectives. With appropriate design, shelter, fodder and timber benefits could also be realised. Planting would need to be on a large scale to capture salinity benefits.

Capturing benefits in addition to soil conservation

<table>
<thead>
<tr>
<th>Other benefits to capture</th>
<th>Opportunity</th>
<th>Thing to look out for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>Trees planted to reduce erosion, stabilise gullies, cycle nutrients or rehabilitate unproductive soils could be harvested for timber if appropriate species are selected</td>
<td>Establishment costs may be high and growth slow on degraded sites. Some soil conservation benefits may be lost through the harvesting process – manage it carefully!</td>
</tr>
<tr>
<td>Salinity and waterlogging</td>
<td>Strips of trees planted to reduce slope length may access laterally moving groundwater and thus have some benefit on water-tables downslope. If enough trees are planted for soil conservation purposes they could reduce or reverse a trend of rising water-tables</td>
<td></td>
</tr>
<tr>
<td>Shade and shelter</td>
<td>Scattered trees, pockets of trees or belts will give shelter to crops, pastures and animals</td>
<td>Planting locations required to address issues of soil degradation may not coincide with those required for maximum shelter effect</td>
</tr>
<tr>
<td>Fodder</td>
<td>The use of fodder species for soil conservation is a good way to get some economic return from land which is being degraded under conventional management</td>
<td>Grazing pressure will need to be strictly managed</td>
</tr>
<tr>
<td>Nature conservation</td>
<td>The opportunity to use native vegetation for soil conservation purposes will potentially enhance wildlife habitat diversity</td>
<td></td>
</tr>
<tr>
<td>Scenic quality</td>
<td>Planting degraded areas will have a positive impact on scenic beauty</td>
<td></td>
</tr>
</tbody>
</table>