Introduction

Saline and waterlogged soils, saline creeks and rising water-tables often trigger interest in tree planting. This raises questions such as: What area of trees do I need to plant? Where in a catchment should I put them? Which species are best?

This chapter will describe the factors that need to be considered when planting trees for controlling salinity or waterlogging and give some principles that can be used to answer these questions. Only generalities can be given here because many of the factors are site-specific.

Since effective salinity control will generally require a large financial and labour investment, it is important to understand your local conditions as well as possible. You should consult local salinity specialists or hydrogeologists. Their input may be the difference between success and failure!

What is the cause of dryland salinity?

Dryland salinity is a groundwater problem – salinity is only a symptom. Salinity occurs when there is an imbalance between inputs of water into groundwater within a catchment and the amount of groundwater leaving the catchment (Figure 4). This imbalance may occur, for example, when native trees are cleared for cropping.

When more water goes into a catchment than comes out, the water-table rises, bringing salt to the surface.

Salts are carried in water moving through soils and the landscape. Salts can then accumulate at the soil surface when groundwater evaporates from shallow water-tables.
Inputs to groundwater are known as recharge. Recharge can come either from the small amount of rainfall that percolates below the root zone of plants, or from water seeping into the groundwater from streams, rivers, lakes and dams. The amount of water that percolates below the root zone of crops and pastures can be 10–100 times that percolating below trees. While all sources of recharge can contribute to dryland salinity, increased groundwater recharge under crops and pastures is the major cause of dryland salinity.

Losses of water from groundwater are known as discharge. Discharge can occur by subsurface lateral flow (when the groundwater flows directly into a stream or river or when it evaporates from soils or transpires from plants). As the groundwater level comes closer to the soil surface, discharge into streams and from soils and plants increases, resulting in increased stream and soil salinity (particularly if the groundwater is saline). If water-table levels are regularly less than about 2 m deep, salts can build up at the soil surface, eventually killing plants and leaving the soil bare and salt-crusted.

However, it should be remembered that groundwater also discharges through transpiration from vegetation on the perimeter of the bare areas, where water-tables are deeper (eg. within 4 m of the surface) and surface soil salinity is less obvious. Groundwaters are often saline in discharge areas, with an electrical conductivity ranging from 6 to over 60 dS/m.

Dryland salinity will be controlled by restoring the balance in a catchment (Figure 5). This can be achieved in two ways:

• reducing groundwater recharge; or
• increasing groundwater discharge.

Planting trees can help in both these processes.
There is no set size of a catchment in the context of dryland salinity. Catchments will vary from a few hectares to large drainage basins (e.g., the Murray-Darling basin) and large catchments can contain many small catchments. Management options for controlling dryland salinity will depend on catchment size and what part of the catchment is being treated (e.g., areas of dominant recharge or discharge). In general, the relief of the land will determine the catchment size that is relevant to dryland salinity problems - the steeper the relief and more hilly the area, the smaller the catchment. It is important to remember that property boundaries are usually different from catchment boundaries.

![Diagram](image)

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**Figure 5: Restoring the balance between groundwater recharge and discharge for dryland salinity control - the four factors that can be managed when planting trees**

### How salty is it? A quick guide to water salinity and units

Water salinity is measured by either the weight of salts in water or, more commonly, the ability of water to conduct electric current - known as electrical conductivity (EC). There are different units for these measures, especially for EC. This table provides a rough guide to a range of common water salinities.

<table>
<thead>
<tr>
<th>Units</th>
<th>Rain water</th>
<th>Tap water</th>
<th>Sea water</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC units (the same as µS/cm - micro Siemens per centimetre)</td>
<td>20 to 50</td>
<td>less than 1 500</td>
<td>50 000 to 60 000</td>
</tr>
<tr>
<td>EC dS/m (deci Siemens per metre; the same as milli mhos per centimetre)</td>
<td>0.02 to 0.05</td>
<td>less than 1.5</td>
<td>50 to 60</td>
</tr>
<tr>
<td>EC mS/m (milli Siemens per metre)</td>
<td>2 to 5</td>
<td>less than 150</td>
<td>5 000 to 6 000</td>
</tr>
<tr>
<td>Milligrams per litre (mg/l - the same as parts per million)</td>
<td>10 to 30</td>
<td>less than 1 000</td>
<td>33 000 to 40 000</td>
</tr>
</tbody>
</table>
Waterlogging is caused by the same processes as dryland salinity. The difference is that salts do not accumulate at the soil surface, either because groundwater is of very low salinity (less than 6 dS/m) or it flows out of the soil (i.e. from a small spring), flushing the salts away. Waterlogging problems can also be ephemeral, such as when a perched water table develops on an impermeable subsoil in a wet season. Most of the information given in this chapter is also directly relevant to management of waterlogging, except the references to salt accumulation and its effects. Thus waterlogging will generally not be discussed separately.

**Design principles**

There are four factors that can be manipulated when designing agroforestry systems for controlling dryland salinity (Figure 5). These are:

- **area** planted;
- the **arrangement** of the trees;
- their **location** within a catchment; and
- the tree **species** selected.

All of these can impact on recharge and/or discharge of groundwater and all need to be considered when undertaking tree planting for dryland salinity control. The principles associated with these factors are described in general below. The optimum design will always be dictated by specific landscape and climatic conditions, as well as by the overall land management objectives and restrictions relevant to the site. Also, the design may be varied to capture some of the other positive benefits of agroforestry (see table at the end of this chapter). Thus, the final design will most likely be a compromise between salinity control and other factors.

To help in determining the final design, the rationale behind each of the principles will be explained briefly. Local input from salinity specialists, hydrogeologists and foresters will be invaluable in the design process and will increase the chance that the exercise will be a success.

**What area of trees should be planted?**

This is an important but, unfortunately, difficult question to answer, because the answer depends on knowing what changes in recharge and discharge rates are required in a catchment to reduce water-table levels. Answers will be region or even site specific. A wide range of areas has been planted with trees in successful attempts at dryland salinity control – ranging from about 30–70% of catchments in parts of southern WA, to the establishment of a few hectares of trees near discharge areas in southeast Queensland.

One **overriding principle is that the impact of trees on the groundwater balance will depend on the area planted – the greater the area, the greater the impact (Figure 6).**

The arrangement, location and species of trees can also influence their impact, as described in the following section. The greater your knowledge about the groundwater hydrology of your catchment, the better you can target tree plantings for salinity control.
**Arrangement of trees**

Trees reduce recharge by using water stored in the soil faster than crops and pastures. The rate at which water can be taken up from the soil by plants is influenced by their leaf area – the more leaves the better! Tree canopies may develop more quickly (and so leaf area increases more quickly) if trees are spaced closely.

**Select a tree density that will give a full canopy as quickly as possible.**

However, the final leaf area achieved is mainly governed by soil, climate and species performance rather than tree spacing, so the leaf area of wider spacings will ‘catch up’ to those of closer spacings after a few years. Therefore, other factors such as access, weed management, species selection, other possible benefits of the trees, etc should also be considered when selecting a tree spacing.

**Maximise ‘edge effects’.** Tree roots can extend considerable distances beyond the edge of the plot. A common distance used is 1½ times the tree’s height, although it could be up to 3 times in some situations. Also, transpiration rates from trees on the edge of plots are often greater than from those in the middle, because trees on the plot edge are ‘dried’ more by winds. Thus, trees will be more effective if they are planted in strips or small clumps rather than larger groups (Figure 7).

**Figure 7: Increase the impact of trees by planting in strips or small groups (note: the total tree area is the same in both arrangements)**

**Location of trees in the catchment**

**Recharge areas**

Groundwaters will be recharged in virtually all parts of a catchment. However, there may be areas where recharge occurs at preferentially higher rates. Examples would be areas of permeable (lighter textured) soil or areas of exposed, fractured rock – that is, places where water infiltrates into soil quickly and can move downwards rapidly. These areas often occur in higher parts of the catchment.

If recharge areas can be identified they should be targeted for tree planting for the greatest impact on recharge and salinity.

Caution is needed, however, as it may not be possible to accurately identify preferential recharge areas. Also, it is possible for several separate groundwater systems to exist in a single catchment. Thus, you need to be confident the recharge area identified is linked to the saline area being controlled. Local knowledge of hydrogeology is vital in this exercise.

**Managing trees for fodder**

It is important to avoid overgrazing trees that have been planted for salinity control, as their leaf area determines the amount of water they can use. Apart from careful management, keeping watering points away from the trees can help reduce the pressure of stock on trees.
Trees for controlling dryland salinity and waterlogging

Discharge areas

Trees (and other deep-rooted plants) can increase discharge rates because roots take up water close to the water-table. However, the high soil salinity levels common in discharge areas cause difficulty with tree establishment and restrict water uptake by trees.

Trees should be planted around the perimeter of salt-scalded soils (the green area in Figure 8, for example), where water tables are slightly deeper and often less saline and surface soils are not obviously salt-crusted or highly saline.

Trees (and shrubs and pastures) can be planted in the saline soils to stabilise the soil and reduce run-off and salt washing away. However, these trees will be much less effective for water-table control than trees on the perimeter of the saline area.

Trees will have the greatest impact on water-table levels if water-tables have a salinity less than 10 dS/m and are at least 3–4 m deep. Also, any factor that prevents tree roots from being active close to the water-table (such as hard pans in the soil) will reduce discharge from plants. It is worth digging a hole to check on soil conditions and collecting information on water-table depth and salinity before putting a large effort into establishing trees in these areas.

Other important benefits come from establishing trees and other plants in the bare scalded/waterlogged soils of discharge areas. These include stabilising the soil and preventing soil and salts from being washed off the site (see chapter on soil conservation).

Interception of lateral groundwater flow

In hilly country, groundwater may flow laterally within the soil down the hill.

If trees can access and use laterally flowing groundwater there will be less water recharging areas further downslope (Figure 9).
This is the philosophy behind ‘break-of-slope’ tree planting, although trees can be located anywhere on the slope where water-tables are shallow for this strategy to apply. This interception of groundwater is an attractive option for enhancing discharge because salt build-up in the root zone is limited. However, there are several factors that may limit the effectiveness of these plantings. If groundwater salinity is greater than 10–15 dS/m and/or water-tables are deep, the amount of water that can be extracted by trees will be small. The amount of groundwater removed by the trees will also be small if only a few rows of trees are planted. Finally, it is possible that the groundwater system being recharged by the lateral flow is not the one responsible for dryland salinity, so there will be no impact on the salinity problem.

**Species selection**

**Plant deep-rooted species**
Trees will reduce recharge by using more of the rainfall that is stored in the soil than crops and pastures. This increased use is due primarily to the ability of trees to take up water deep in the soil profile – very little water escapes the root zone if it is 6 m deep. Additionally, trees will enhance discharge more if their roots can reach deep water-tables.

For salinity control, tree species should be selected that have the potential to grow deep root systems (such as many eucalypts).

Local nurseries or forestry departments should be able to give advice on the species suitable for specific areas. It should be noted that soil conditions (rock, hardpans, acidity, etc) may limit the depth to which roots can develop, limiting the benefits of trees. It is worth augering a hole to at least 3 m to see if there are any impediments to root growth before planting trees in either recharge or discharge areas.

**Plant salt tolerant and/or waterlogging tolerant trees in discharge areas**
Salt tolerant trees will establish more successfully and grow better in the saline soils that commonly occur in and near discharge areas. Similarly, if waterlogging is a problem, waterlogging tolerant species should be selected.

Salt tolerant trees will also contribute more to groundwater discharge than will salt-sensitive species.

Marcar et al. (1995) have provided a comprehensive guide for selecting native species for saltland planting.

**Plant species that perform well locally**
There is little point in investing time and money in establishing tree species that will not grow well in your district. Local nurseries or forestry departments will give advice on the species that are both suitable for specific areas and exhibit the characteristics described above.
Other factors

Before finalising any design for planting trees to control salinity, there are additional factors that should be considered.

Where does your farm fit into the catchment?

Dryland salinity is a catchment-wide problem. If you have obvious salting on your property you are at the discharge ‘end’ of the catchment (Figure 10, location A) or subcatchment (Figure 10, location B). But do you control the recharge areas too? If not, as is the case in location A of Figure 10, some of the options described above may not be available to you. You should also remember that both surface water and groundwater may flow from your discharge area into another property or catchment (as at location B in Figure 10).

Alternatively, if you do not have any signs of salinity on your property you may be in the recharge zone of the catchment (location C in Figure 10) and your management choices may impact on others lower in the catchment.

Because salinity does not respect property boundaries, a ‘whole of catchment’ approach will be most successful in managing the problem. You should become involved in a catchment management committee or landcare group if one exists in your area, or consider starting one if not. Also, consult your neighbours to develop a coordinated approach to salinity control.

Time-scales

There are time lags involved in the cause and effect of dryland salinity. It commonly takes several decades (and possibly centuries) after clearing trees before dryland salinity problems appear. The reverse is also true – it may take equally long after re-planting trees to ‘fix’ the problem. Unfortunately, it may take even longer because fewer trees will generally be replanted than were cleared.

Strategies for controlling dryland salinity need to be integrated into long-term farm and catchment management plans.

Consider all sources of recharge

Any input of water to the groundwater will exacerbate dryland salinity problems. Such inputs can come from farm dams (especially if poorly sealed), irrigation or poorly controlled run-off. All possible sources of recharge should be considered when devising management plans to control dryland salinity.

Dams should be checked for leaks, irrigation should not be applied in recharge areas, and banks should be built to keep run-off away from recharge areas.

Consider the role of other plants

Trees are not the only means of managing dryland salinity. Perennial pastures have a role in reducing...
recharge and managing discharge areas. Fodder shrubs may also be useful. The principles given in this chapter can be applied to any type of plant to judge its role in managing salinity.

**Engineering options for enhancing discharge**

There are also 'engineering' options for balancing recharge and discharge, such as draining water tables and pumping groundwater from bores. They have some drawbacks that limit their use, such as cost, disposal of the water (see the hints box), and the suitability of hydrological conditions (this will affect drain spacing, flow rates from bores and other design criteria). Nevertheless, engineering options may have a role in controlling dryland salinity, especially in conjunction with other measures such as planting trees, so should be considered when devising management plans.

**HINT**

**Can you use the water from your shallow water-table?**

One way to lower water-tables is to pump water from them. The cost of this can be offset if the water is used for some productive purpose. It may be possible to use it for stock or supplementary irrigation (even to water salt tolerant trees), depending on its salinity. Advances are being made with low-flow irrigation systems and the management of saline irrigation water which make these options increasingly feasible. These options are worth considering - water is too valuable a resource to waste!

**How do you know if you are being successful?**

There are a number of attributes of a catchment that can be monitored to assess the effect of your actions to manage salinity. These include water-table depth and salinity, stream salinity (if there is a stream there), the size of the salted area, tree growth and survival and the mixture of species growing in paddocks. Some of these, such as the area of salted soil or the rate of tree growth, are fairly obvious and so it is easy to think there is little need for formal (ie written) record keeping.

Changes can be deceptive and may be related to other factors (such as weather), so more formal records are useful.

Some details of monitoring these are given below.

**Water-table depth and salinity in discharge areas**

The depth of water-tables can be easily measured in wells or bores in discharge areas to check if they are getting deeper (or shallower) with time. If there are no wells present, they can be installed quite easily (see the hints box on next page). Small EC meters can be purchased for measuring the salinity of water samples. Alternatively, water samples can be taken to local departments of agriculture or conservation where salinity measurements can usually be arranged.

You should check with your local hydrogeologist before monitoring existing wells or bores. If there is more than one groundwater system in a catchment, existing bores may not be in the systems that are responsible for your salinity problem. This is particularly likely with deep bores. In that case it would be best to put in a shallow well solely for measuring water-table heights.

Water-table levels will be affected by short and long term weather patterns, as well as by changes in land...
management. For example, water-tables will be deeper after a run of dry years than after a run of wet years. Also, water-table salinity may change after a season (or drought) breaks. Thus, the impact of tree planting cannot be judged from only a few measurements.

**Measurements need to be made regularly** (every 1-3 months is best) over a few years to a decade to establish any trends.

Records of the weather are needed, too, for establishing patterns. Another factor that will influence bore or well water levels is the amount of water pumped out of the bore or well if they are used to provide water for stock, etc. It may be best to put in a shallow well solely for measuring water-table heights if the existing ones are used for water supply.

**Stream salinity**

Water can be sampled from streams flowing through salted paddocks and its salinity measured. As with measuring water-table levels, records need to be kept for a number of years to establish trends. In addition, the depth of the stream needs to be measured or estimated when salinity is measured. Rain makes streams run but dilutes the salinity of the stream water.

**Lower stream salinity after rain or during wet years is not a reliable sign of an improvement in the salinity problem.**

**Area of scalded soil**

Changes in the area of bare scalded soil are directly related to improvements or worsening of the salinity conditions in a paddock or catchment. Often, the area will change relatively slowly, more over decades than years. It may also be influenced by weather conditions over a few years. For example, soil will look better after a run of dry years than after a run of wet years because of the effect of weather on water-table depths.

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**HINT**

**Installing a well to measure the depth of shallow water-tables**

A suitable bore for measuring water-table levels can be made fairly easily. A hole needs to be dug with a hand auger, post-hole digger or drill to a depth of 2–3 m. PVC stormwater pipe can be used as the casing.

Fix a cap to the bottom end of the PVC pipe. Cut slots around the bottom half to one metre of the pipe with a hacksaw or angle grinder, to let the water in. Backfill the hole around the pipe with gravel (1–2 cm diameter), up to 30–60 cm from the soil surface, to keep soil out of the pipe. Then backfill the rest with clay or cement to prevent water from running down the outside of the well.

Put a cap on the top, but make a small hole or cut in the side of the pipe below the top cap to allow air to move in and out. Keep the pipe fairly short above the ground if cattle are around, as they will knock it over.

A series of measurements every year or two is necessary to establish trends.

Changes will need to be considered with respect to the weather, so rainfall records are useful too.

A good way of assessing bare areas is from aerial photographs. Aerial photographs are taken of many parts of the country every few years and held in a library within the state government department responsible for mapping and surveying. Copies of these photographs can often be purchased or borrowed. It is valuable to obtain a series of these photographs (say, one or two per decade) to follow the development of the salted area through time.

Another way to monitor the change in area of salted soil is to use electromagnetic induction...
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(EMI) meters. These sense soil salinity through the soil's ability to conduct magnetic fields and are a rapid way of surveying soil salinity. Measurements could be made every year or two. These instruments are costly and generally require calibration or experience at interpreting the results, so their use should be arranged through local departments of agriculture or conservation.

Tree growth
Where trees are planted, their survival and growth can be recorded. This is particularly handy if different species are planted to provide a good record of which preformed best. Growth rates can be deceptive - if trees are growing 1 m per year, for example, the growth of small trees only 1 or 2 m high may be more noticeable than the growth of larger trees.

It is worth making measurements of tree growth about once a year. Evidence of insect attack, other pests, susceptibility to frosts or waterlogging, etc should also be noted.

Species mixtures in paddocks - look for indicator species
Certain plants tolerate salinity better than others and thus are more common in saline soils. Examples are naturally occurring salt bush species and some common pasture grasses (such as sea barley grass in southern Australia and Rhodes grass in northern Australia). These species are often called indicator species, as their presence indicates the onset of salinity.

It is useful to determine the indicator species in your district and check if they are present in a paddock.

If they are spreading over time, salinity levels may be rising! Local departments of agriculture or conservation will have information on indicator species.

References / Further reading

- Salinity - A Situation Statement for Western Australia. G overnment of Western Australia, Perth, 1996.
When planting trees for the management of salinity and waterlogging, 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 offer a good opportunity to capture nature conservation and scenic beauty objectives. Designs to manage salinity are also compatible with shelter and fodder objectives, depending on layout and species choice. Soil conservation and timber product objectives can also be realised.

### Capturing benefits in addition to salinity and waterlogging

<table>
<thead>
<tr>
<th>Other benefits to capture</th>
<th>Opportunity</th>
<th>Thing to look out for</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wood</strong></td>
<td>Recharge areas, which are planted to reduce additions of water to the water-table, can also be favourable locations for the production of wood products. Trees planted on slopes to intercept laterally moving groundwater before the water mixes with saline groundwater can have fast growth rates (break-of-slope plantings).</td>
<td>Tree species and planting locations required to address issues of salinity may not coincide with those giving the best productivity or returns. Trees planted in saline discharge areas will often have poor wood quality and slow growth and may die before maturity.</td>
</tr>
<tr>
<td><strong>Soil conservation</strong></td>
<td>Trees planted for salinity management could coincide with sites requiring erosion control. Revegetation of saline areas may prevent salt- Scalped areas from being eroded. Nutrient cycling by trees can ameliorate saline soils.</td>
<td>Tree species and planting locations required to address issues of salinity may not coincide with those required for soil conservation management.</td>
</tr>
<tr>
<td><strong>Shade and shelter</strong></td>
<td>Strips or belts of trees are favourable designs both for salinity management and shelter effects. Large areas of trees planted for salinity control can achieve a shelter effect at the ‘regional’ scale.</td>
<td>Sites requiring trees for dryland salinity control may not match those sites requiring shelter. Trees planted on saline soils may not be effective windbreaks.</td>
</tr>
<tr>
<td><strong>Fodder</strong></td>
<td>Trees established for salinity control can provide an important source of fodder on either a regular basis or in times of feed shortages.</td>
<td>Leaf area is important in determining tree water use (and salinity impact), so over-grazing should be avoided. If fodder species are shallow-rooted, they will not have the same impact on salinity as deep-rooted trees.</td>
</tr>
<tr>
<td><strong>Nature conservation</strong></td>
<td>Strategic planting in recharge and discharge areas provides opportunities to simultaneously provide wildlife habitat, especially if native species are planted. Break-of-slope tree plantings can serve as wildlife corridors if the plantings are sufficiently dense and link existing remnant vegetation.</td>
<td>Spreading trees out for the purpose of using more water over a wider area conflicts directly with a nature conservation guideline to minimise edge effects.</td>
</tr>
<tr>
<td><strong>Scenic quality</strong></td>
<td>Revegetation for salinity control will generally increase scenic quality depending on species type and planting layout.</td>
<td>Poor tree growth and potential death will reduce scenic quality.</td>
</tr>
</tbody>
</table>