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Tree planting to control salinity

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This Primefacts includes information on tree-planting for restoring hydrological balance and thus reducing the incidence of dryland salinity.

Introduction

Secondary dryland salinity is partly a result of large-scale clearing of native vegetation from the landscape, allowing an increased amount of rainfall to permeate through the soil (recharge), causing rising watertables. In the Murray–Darling Basin, dryland salinity worsened in the latter half of the 20th century as the increased potential recharge due to clearing was superimposed on the long-term wet climatic phase (Rancic *et al* 2009). This additional water can mobilise and transport salts stored within rocks and soil to other parts of the landscape or streams (see box opposite), as well as causing watertables to rise.

Irrigation salinity occurs when water from excessive irrigation drains below the root zone of plants and mobilises stored salts in the soil. This leads to elevated saline watertables. Levels of watertables have risen by 30 metres since the 1880s in parts of south-eastern Australia (WA Dept of Agriculture and Food 2004).

When the watertable is within one to two metres of the surface, evaporation creates a capillary action which draws the saline water up through the soil profile and concentrates the salts near the surface, in the root zone of plants.

It has been estimated that at least 180,000 ha of NSW is currently affected by dryland salinity or has shallow watertables (<2 m deep), with an imminent risk of salinity. Over 90% of the land currently affected is designated agricultural (Littleboy *et al.* 2001).

Many types of dryland salinity can be controlled by reintroducing trees and other deep-rooted vegetation into agricultural landscapes, to restore a hydrological balance.

Salinity terminology

Primary salinity – naturally occurs widely within the Australian landscape, as in salt marshes, salt lakes, tidal swamps, or natural salt scalds.

Dryland salinity – on non-irrigated land, occurs when the concentration of soluble salts near the soil surface is sufficient to reduce plant growth.

Secondary salinity – dryland salinity attributed to human activity which causes a change in the water balance (particularly clearing of deep-rooted perennial vegetation for pastures and cropping) leading to a rising watertable. Salt may accumulate in the soil, groundwater, or surface water.

Irrigation salinity – a localised rise in the level of groundwater and the associated mobilisation of salt, caused by the application of large volumes of irrigation water, poor drainage, or seepage from irrigation channels or dams.

Transient salinity – may occur when the upper soil layers are sodic (with a high exchangeable sodium percentage), and results from seasonal movement of salt into and out of the soil profile due to evaporation and rainfall.

Recharge – water that leaks through the ground surface into the watertable (groundwater), below the root zones of plants. It may vary greatly over a catchment depending on the nature of surface rock, and with rainfall. Surface sands, gravels and fractured rock allow rapid entry of water.

Discharge – the loss of groundwater from a catchment by subsurface flow; surface loss into streams or seeps; or transpiration by plants. Some of these mechanisms may cause salinity in water bodies within or outside the catchment.

Salinity Indicators

Dryland salinity can manifest itself in a number of ways. Visual indicators provide a quick and easy way of identifying saline ground-water discharge areas:

- bare or sparsely vegetated ground, which may have visible salt crystals on the surface;
- continuously or seasonally wet or waterlogged ground;
- stock congregating on saline areas to lick the salt from the ground;
- along waterways, salt crusting that is evident along the water's edge; the water may appear very clear;
- bare soil that is be 'puffy' to walk on when dry.

Vegetation can also be an indicator. Changes in vegetation communities to saline tolerant species can be an indicator of saline soils, although many saline-tolerant species will grow under a range of conditions.

For further information see:

Salinity symptoms Primefacts 939 http://www.dpi.nsw.gov.au/agriculture/resources/soils/salinity/general/symptoms

Original sources of salt in New South Wales

Salt in soils and waterways in NSW originates from several sources, including

Aeolian (wind-transported) salt – from sedimentary deposits including dune sand and aggregated clay parna (Parna is an Aboriginal word used to describe aeolian deposits containing a mixture of sand, silt and clay.) Dry, windy periods over geological time mobilised soil with salt attached, which was generally transported in a west–east direction across NSW from more inland areas. Soil and salt were deposited on plains, slopes and tablelands.

Cyclic salt – salt from ocean spray or in rainwater, deposited at up to 15–30 kg/ha/year in inland areas.

Connate salt – in marine sediments deposited when Australia was partly covered by the sea. Rock weathering allows salt to be released as minerals break down (NSW DPI 2007a)

Salinity management

Salinity management on a farm generally aims to reduce the area affected by salinity and ameliorate the problem in affected areas. Recharge rates to aquifers under intact native vegetation are normally very low in areas with low to medium rainfall. The use of deep-rooted plants such as trees is an important part of salinity management, aiming to reduce rates of recharge and discharge.

Effective salinity management ideally needs to be conducted on a catchment-wide scale. It is essential to have an understanding of the geology and hydrology of the catchment, including the scale of the groundwater system, its physical structure and discharge capacity, as well as recharge rates for each land use. The location and size of required plantings can then be worked out more accurately.

For large catchments this may involve consultation by a landowner with the Catchment Management Authority (CMA), local Salinity Officer, and other land owners. Work planned by landowners should tie in with catchment management plans of the CMA. CMAs use catchment decision support systems such as SCaRPA and its Salinity Benefits Index tool (Murrumbidgee CMA 2006) to identify priority sites for remedial action. Landowners may be eligible to apply for incentive payments.

Electrical conductivity

Salts are chemical compounds that have a positive or negative charge and will therefore carry an electrical current. By measuring how readily the current flows, or in other words the electrical conductivity (EC), the level of salinity of a soil can be determined. Appropriate measures of soil salinity from the point of view of plants are the EC of the extract of soil paste (EC_e) or the EC of a 1:5 soil:water extract ($EC_{1:5}$). EC is measured in deciSiemens per metre (dS/m)

Use of trees and shrubs to combat salinity

Plants may be used to: (1) reduce groundwater recharge by using water in the root zone and minimising recharge of (or 'leakage' to) deeper aquifers; (2) reduce saline or potentially saline groundwater levels (make them deeper beneath the ground surface) through roots directly accessing the watertable and increasing discharge. Native trees and shrubs are effective water-users with deep roots that can use water stored deep in the soil profile. They are opportunistic water users able to continue transpiring in summer when annual pastures have browned off, and they respond rapidly to rainfall.

Tree water use

There are many factors that affect the amount of water consumed by trees. Research on young plantations of native trees growing in dryland areas shows that tree water use is largely affected by season, current weather patterns, salinity level, and plantation age. Many tree species can use water of EC 5–8 dS/m, and some more salt-tolerant species can use substantial amounts of saline groundwater (EC up to 16–20 dS/m) (Marcar and Crawford 2004). Research by I&I NSW at a site near Quirindi, NSW, showed that at a planting density of 1000 stems per hectare, ironbarks (*Eucalyptus sideroxylon*) aged 6–10 years were each using up to 5 mm of non-saline water per day (50 L per tree), during hot summer days with good access to water. Water use dropped substantially during drought periods when water availability (either soil moisture or groundwater) was low – see Figure 1 below.

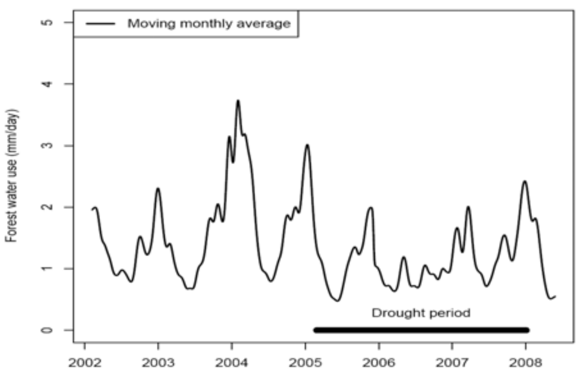

Fig. 1. Water use by E. sideroxylon near Quirindi, 2002–2008

Studies in Victoria showed that eucalypts planted on recharge sites, and aged 6 and 20 years old, used an average of 100 and 160 litres each per day in early summer when soil moisture was ample. Trees over 100 years old each used up to 450 litres per day in summer (Clifton and Perry 1999).

A 15-year-old tree belt located in central-west NSW with access to saline groundwater (3 dS/m) used double the water used by a nearby tree belt with no access to groundwater. The first tree belt operated in an energy-limited environment, transpiring at a rate equivalent to the atmospheric demand, whereas the second belt was water-limited. From a land management point of view, the establishment of more trees on the discharge site would have the greater effect in reducing saline discharge and the least impact on agricultural operations (Crosbie *et al*. 2008).

Natural forest and woodland

Wherever possible, natural established or regenerating forest and woodland should be retained, especially in upper catchment areas and salt-prone areas. This is the first line of defence against salinity spread, and such areas are also likely to be valuable for maintaining biodiversity and for storing carbon.

Plantings in recharge areas

To reduce recharge (leakage to aquifers), planting of trees and shrubs is recommended on areas where this occurs – generally ridge and upper slope locations. The aim of this vegetation is to intercept and use as much rain as possible before it enters the groundwater system, and it should be able to survive dry periods. However, it should be noted that determining the location of recharge zones can be difficult as these areas can be large and diffuse. To properly target plantings, it is important to understand local groundwater processes and not valid to extrapolate findings from one catchment to others.

Soil factors and recharge

Recharge rates are higher in soils with large pores and low water-holding capacity (e.g. sandy) and lower in clays with very small pores and high water-holding capacity. Recharge may also be increased by leakage beneath farm dams. As an example, George (2007) presents a scenario for a hypothetical 2,000 ha farm in south-western Western Australia, in which annual total recharge volume was minimised by planting all sandy areas (600 ha) to trees. Recharge in this case was calculated as 170,600 m^3 compared with 350,000 m^3 from a traditional crop and pasture rotation over the property.

Plantings for increasing discharge from watertables

Tree/shrub planting may be beneficial for (1) removing relatively fresh water at break-of-slope situations, or (2) for intercepting relatively fresh perched or laterally-flowing groundwater, if such water in either case is likely to augment a rise in a saline watertable. Watertables may be lowered by trees if they can use the groundwater directly and inflows from surrounding areas are low. Local groundwater systems within small catchments tend to have more easily identified discharge zones. Discharge plantings are most likely to lower the watertable where:

- roots can penetrate through the soil profile to the watertable (no hardpan in soil);
- trees are tolerant of waterlogging;
- watertables are between 3 and 5 m deep. If shallower, root zone salting may limit tree water use;
- watertable salinity is less than EC 8–10 dS/m. Higher salinity will reduce the trees' ability to take up the water and they will grow more slowly.

(Thorburn and George 1999)

Hydrogeological factors

Preventing salinisation by recharge control may not be practical or economic in areas where groundwater gradients are very low so there is little and very slow water flow below ground, or if recharge is highly irregular (e.g. large, irregular recharge from cyclones), or if discharge areas are very small relative to recharge areas (George 2007).

Strategies for locating plantings may vary according to the local geology. Native pastures and/or trees and shrubs are planted in hilltop and upper slope positions, i.e. recharge zones, in all geologies. In **granite landscapes**, groundwater flows are predominantly laterally down-slope above the bedrock. Trees and native pasture on the mid-slope will help to intercept this lateral flow. In **sedimentary landscapes**, water may perch above impermeable, horizontal rock layers lower down hills. Trees and native pasture on the mid-slope can intercept this perched groundwater. **Metasedimentary landscapes** have fractured geology, in which water can flow through subsoil and bedrock. The main priority for trees and native pasture is to reduce recharge on hilltops and upper slopes. In **basalt landscapes**, groundwater may perch between the fractured basalt and less permeable rocks below and discharge as springs and seeps on hill slopes. Trees and shrubs could be planted at these points of discharge. The NSW DPI *Salinity Glove Box Guide* (2007) contains useful information and diagrams of landscape management to control salinity.

Plantings in saline or waterlogged areas

Waterlogging is often associated with saline soils or sodic soils with low permeability. Plants suffer through decreased oxygen, which reduces root growth and viability, and inability to exclude sodium and chloride.

Establishing any vegetation on saline scalds is difficult and is dependent on a range of physical and chemical conditions, coinciding with a favourable climatic period.

The expression of salinity within saline scalds varies with time and space. Studies measuring this variability show that bare patches within the scald have significantly higher soil salinity than patches that support vegetation. Paired soil sampling from a saline site in the central west of NSW show that bare areas have an average $EC_{1:5}$ of 10 dS/m compared with neighbouring vegetated area with $EC_{1:5}$ of 0.2 dS/m (Semple *et al.* 2006).

Successful tree establishment can be aided by mulching and mounding (Semple *et al.* 1998) on areas within the scald already vegetated. If saline soil conditions in seeps and scalds will prevent successful tree establishment, then planting would best be done adjacent to the seeps or scalds rather than directly on them. This is because soil conditions are more favourable away from these features, and plant roots may access groundwater of lower salinity. If trees adjacent to a seep induce the watertable to drop, the salinity of the surface soil may fall, allowing more trees, grasses or crops to be planted towards the centre of the seep (Marcar and Crawford 2004).

Examples of plantings influencing salinity or groundwater

A detailed characterisation of a site in the central-west of NSW, where 60 ha of trees were established above a saline scald in a small sub-catchment of the Little River in 2002, indicated that salt stores within the landscape were patchy and probably of aeolian origin (Acworth *et al*. 2009).

Large salt scald from the air (I&I NSW Photo Library)

The growth and shrinkage of various salt scalds in the region correlated with historical rainfall patterns. Results from the study suggested that targeted planting of trees to prevent recharge into the localised salt stores would be beneficial, but broad-scale planting might reduce dilution flows to the stream.

A saline scald developed near the bottom of a 130-ha first-order catchment near Boorowa, NSW (Boorowa Key Site – NSW DPI 2007b) in the early 1990s. The owner then undertook land use changes including perennial pastures and alleys of trees on 20% of the area to minimise recharge. Data collected over 13 years have indicated a great reduction in recharge, reduction in runoff, and halving of the salt output from 56 tonnes to 26 tonnes per sq km. The reduced salt is mostly due to the reduce volume of water being discharged off the site rather than a reduction of the EC of the water (NSW DPI 2007).

Studies in the Shepparton area (Vic) indicated that planting trees or trees and deep-rooted pastures to reduce recharge is most successful in hillslope areas where recharge and discharge zones are close together (Daamen *et al.* 2002). At Burke's Flat (Vic), for example, conversion of most of a small (900 ha) catchment to perennial pastures, with trees planted on high volume recharge areas along a ridgeline, considerably reduced groundwater levels in discharge areas at the base of the catchment, by about 2.5 m in 11 years (Reid 1995).

These contrasting findings highlight the difficulties in recommending a 'one size fits all' solution to dryland salinity. For instance, in the Little River catchment, localised tree planting on the salt stores would appear to be the best solution. However, at Boorowa and Burkes Flat a widespread intervention was required, over large portions of the catchments.

Site assessment is crucial to determine the most effective intervention strategy to reduce recharge. Trees may need to be planted extensively (in alleys or patches) over at least 30–40% of a catchment to reclaim extensive saline areas, though smaller plantings can lower watertables if strategically placed, such as on perched aquifers or at the break of slope. Additionally, planting trees directly on salt stores, if able to be done successfully, can limit recharge and hence reduce the probability of mobilising salt without affecting dilution water flows (Dr D. Mitchell, I&I pers comm.).

Plantings that include trees interspersed with deep-rooted native and exotic perennial pastures may be a more feasible and economical option for farmers in many cases. The final choice of control strategy will depend on a range of factors, not only those discussed here; these may include economic and social considerations.

Choice of tree species

A detailed account of many tree and shrub species suitable for planting in soils of different degrees of salinity is given by Marcar and Crawford (2004).

Non-saline and low-salinity areas (Soil EC_e <4 dS/m)

If there are no problems with soil or groundwater salinity (such as in ridge/upper slope recharge area plantings) the choice of plant species is dictated mainly by local climate, soil type, and other purposes of the planting. Most species that tolerate higher salinity would of course also grow well in these conditions. In recharge areas on ridges and upper slopes there is often scope to plant more 'traditional' commercial tree species that require well-drained sites, such as spotted gums (*Corymbia* species), ironbarks (e.g. *E. sideroxylon* and *E. tricarpa*), southern blue gums (*E. globulus* sub-species *bicostata*), and sugar gum (*E. cladocalyx*). In areas of poorer drainage, such as some discharge areas or perched watertables, extra potentially commercial species may be suitable – *E. botryoides, E. microcarpa*, *E. saligna, E. viminalis,* and *Pinus brutia*. These species would all grow on well-drained sites as well.

Moderately saline areas (EC_e 4–8 dS/m)

Potentially commercial tree species are more limited. They include *Casuarina cunninghamiana, E. argophloia, E. camaldulensis, E. melliodora, E. moluccana,* possibly *E. sideroxylon, E. tereticornis, Pinus pinaster,* and *Pinus radiata*. The *Pinus* species require good drainage. Among the shrubs, several *Acacia* and *Melaleuca* species will tolerate these conditions.

Spotted gum plantation in non-saline recharge area near Wagga Wagga (Photo: I. Johnson)

Highly saline areas (EC_e 8–16 dS/m)

Few tree species presently regarded as having commercial potential are suited to highly saline areas. *E. occidentalis* and *Casuarina glauca* would be suitable. Some provenances of *E. camaldulensis* may also tolerate these levels of salinity. Several smaller eucalypt species from WA and some larger Melaleucas and Acacias are also sufficiently tolerant. Normally, plantings on these types of sites would not be intended for wood production but more as salinity reduction/habitat enhancement plantings. For extremely saline areas (EC_e over 16 dS/m), there are few large shrubs or trees suitable. Very salt-tolerant species include *Casuarina obesa*, *Acacia stenophylla*, and a few Melaleucas. A mixture of widely-spaced trees or shrubs and saltbush may be appropriate.

Genetic selection

Trees from different provenances (geographic origins) within a species may vary widely, and some may have adaptations different from the average of the species. *E. camaldulensis* shows great provenance variation in salinity tolerance as well as growth. For example, in glasshouse trials, Lake Albacutya (North) and Lake Hindmarsh (South-East) provenances (Vic) showed relatively high tolerance of salinity, and Lowan Valley (Vic) and Silverton (NSW) provenances showed low tolerance (Marcar *et al.* 2002). Families or individuals in other species displaying salt tolerance and good growth in field trials may be propagated for wider testing and some of them may ultimately prove to be superior. Some organisations have been developing clones tolerant of salinity and waterlogging over recent years. The aim is to produce genotypes that can be grown for wood production on sites presently very marginal for this use. For example, Saltgrow™ markets several field-tested clones of pure *E. camaldulensis* and hybrids of this species with *E. grandis* and *E. globulus*, which have achieved mean diameter and height up to about 7 cm and 6.8 m within two years on a moderately saline site (Clonal Solutions Pty Ltd undated).

Other considerations in choosing species

In choosing tree or shrub species to plant, one needs to consider whether a favoured species has the potential to become a weed species and should therefore be avoided. Some wattles have shown a tendency to spread along road verges and crowd out local indigenous species (e.g. *Acacia saligna, A. podalyriifolia*, *A. baileyana*). In plantings with combined salinity/biodiversity or other environmental purposes, it is preferable to plant local native plant species unless there are none that can perform the role of lowering the watertable, etc., as effectively as some non-local species.

Establishing trees

Site preparation for planting – well-drained sites

In well-drained areas (more up-slope recharge areas generally) with low-salinity groundwater, site preparation for tree planting will generally involve ripping to depths up to 60–70 cm, along contours, and possibly mounding. Deep ripping (using a winged tine) and mounding should be done approximately six months prior to planting, ideally when the soil is neither too wet nor extremely dry, in order to shatter the sub-soil and encourage root penetration. A more detailed account of recommended tree establishment methods for better-drained sites, including weed control and fertilising, is given in a separate publication – *Farm forestry in low rainfall areas of NSW* (in preparation).

Site preparation – waterlogged sites

Drainage to ameliorate any waterlogging should be installed before other site preparation is attempted. On such waterlogging-prone sites, deep ripping to at least 60 cm, with 1 to 3 winged tines should be done across contours, to assist drainage, unless there is a danger of soil erosion. Carry out ripping about 6 months ahead of planting, ideally when soil is not very wet, to achieve shattering at depth. Ripping of dispersible soils is not recommended.

Mounding is essential on sites prone to waterlogging, with mounds positioned over the rip lines. The most effective mound for a heavy, saline soil is a wide and tall mound at least 1–1.5 m wide by at least 0.5 m high with a trough down the middle thus producing two ridges (see diagram below). A study in Western Australia (Ritson and Pettit 1992) found that seedlings planted in a 0.5–0.9 m wide trough between mound ridges, and with a mound height of between 0.5 m and 1 m, had the highest survival rates. This mound design is preferable to a single ridged or flat-top mound. A single-ridge mound tends to shed rainfall and wet-up from the watertable or the furrows beside the mound, causing salt to accumulate in the mound. In contrast, the trough of a double-ridge mound tends to collect rainfall, favouring percolation and leaching of salts from the seedling root zone (Ritson and Pettit 1992).

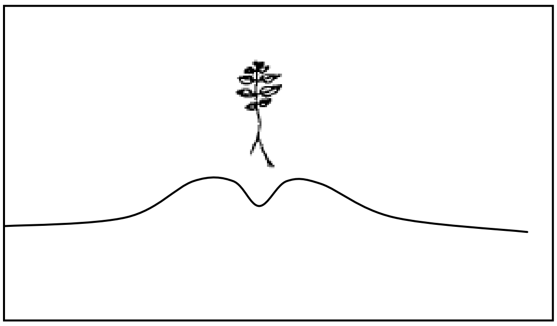

Fig. 2. Double-ridge mound

Seedlings or direct seeding?

Seedlings are generally the preferred method of tree establishment on saline sites, especially if trees are being grown and the site has high salinity or is waterlogged. However, there are cases where direct seeding has been successful, e.g. salt-tolerant trees and shrubs have established in WA when seeded onto saline riparian areas where surface soil is scalped to remove banks of weed seed (Marcar and Crawford 2004). Direct seeding is generally more relevant for environmental tree plantings rather than commercial planting. A discussion of direct seeding is included in the I&I NSW Primefact *Planting trees for biodiversity*.

Seedlings should be planted after good soaking rains or irrigation so that soil moisture levels are high and salts have been leached down the soil profile away from the root zone. Mulching will assist establishment of seedlings in the critical first six months, helping to reduce the loss of moisture from the soil and reducing the accumulation of salts at the surface. This is probably only feasible for limited numbers of trees on particularly harsh sites, where they need special care to grow.

Plantation configuration

Planting densities (trees planted per ha) will vary depending on the severity of the salinity problem and whether or not a commercial return is achievable and or desired. Dense plantations of 500+ trees/ha are the best means of achieving rapid control of groundwater recharge. Commercial plantations on nil or low salinity recharge sites are commonly planted at 800–1000 trees/ha at about 4 m row spacing, and would be compatible with recharge control. In low rainfall areas they can be non-commercially thinned early to concentrate growth on the better stems. In the agroforestry scenario, final crop tree densities of 75–150 per ha may also be sufficient to control recharge, especially if combined with deeper-rooted pasture (Clifton and Perry 1999). Environmental plantings with a similar tree density and a shrubby understorey should achieve a similar result.

For plantings aimed mainly at increasing site water use with nil or limited commercial prospects (e.g. on saline discharge sites), it is more cost effective to plant at about 500–800 trees per ha and avoid later non-commercial thinning. To achieve a financial return, trees on such sites could be used for firewood and allowed to re-shoot (coppice) after harvest to give a future wood crop.

If the primary objective is to reduce the watertable level as quickly as possible, a high density planting (over 1000 trees per ha) could also be employed. This may need to be combined with a thinning regime because once the watertable had been lowered, trees would compete for available soil moisture and nutrients.

Alley-farming configurations have been used on sandy soils in WA, with trees planted in narrow belts over extensive areas, interspersed with annual or perennial pastures or crops. The use of perennial rather than annual pasture may reduce recharge by up to 50% (George 2007). A typical alley layout is 3-row tree belts alternating with strips of pasture 20–30 m wide.

Water use issues

Fears have been expressed that widespread planting of deep-rooted vegetation will greatly reduce water available to creeks, rivers, or lakes. Water availability is often restricted in any case in the 500–700 mm rainfall zone, so it is of particular concern in this zone. This has become a major issue in some parts of the world, such as South Africa, where large areas of industrial plantations are established in regions of monsoonal climate. A densely-planted young tree plantation may use more water per ha than a more open stand of old trees (Clifton and Perry 1999). This is desirable where the aim is to intercept precipitation in recharge areas and maintain or lower saline watertable height. Young plantations in the 600–800 mm rainfall zone may reduce runoff by 100–150 mm per year relative to catchments which are predominantly grass (Plantations 2020 undated).

The impact on water yield in at least small catchments (<1,000 ha) is expected to be minimised by dispersing tree plantations across the landscape in relatively small blocks, restricted to less than about 20% of the catchment area in total (Bureau of Rural Sciences 2003). Thinning to a lower stocking rate before about 6–8 years of age will also lower water use per area, though only temporarily. Targeting plantations to particular areas where their water use is expected to have salinity reduction benefits becomes important in catchments where broader-scale tree establishment could reduce water supplies for other high priority uses. Vanclay (2009) postulates methods of plantation design and management, such as thinning or pruning edges that could reduce water interception and evapotranspiration by trees where such reduction is warranted.

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