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Nick Schofield

Phil Scott

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Planting trees to control salinity

By Nick Schofield, Water Authority of Western Australia, Leederville, and Phil Scott, Department of Agriculture, South Perth

Dense tree plantings covering at least 30 percent of cleared land can lower groundwater levels by two metres or more in 10 years from the time of planting. This sizeable drop can be expected at sites receiving 700 to 800 mm of rain a year.

Research by the Water Authority of Western Australia shows the most promising strategy when using trees is to put dense plantings on the discharge zone and on lower to midslopes. This strategy is successful where groundwaters contain less than 30,000 milligrams per litre total soluble salts (TSS).

At lower rainfall sites (less than 500 mm of rain a year), it is likely that smaller plantations of more widely spaced trees would be effective.

This article discusses research in the 450 to 800 mm rainfall zone by the Water Authority, the Department of Agriculture, the Department of Conservation and Land Management (CALM) and CSIRO.

Need for trees

The replacement of the perennial, deep-rooted native vegetation with annual, shallow-rooted agricultural plants results in more rainfall percolating beyond the plant root zone and recharging groundwater systems. This leads to rising groundwater levels.

Rising groundwaters dissolve salt that is normally stored in the soil profile. The salt is mainly sodium chloride (common table salt) and comes from the sea, being transported by wind and rain. Over thousands of years it has accumulated in the soil.

The rising salty groundwaters eventually reach the soil surface and discharge through hillside and valley floor seeps (Figure 1). This may occur after only a few years in higher rainfall areas, but could take 50 years or more in low rainfall areas.

Evaporation of water from the seepage areas concentrates the salts at the soil surface and makes conditions even more difficult for plant growth. The combination of salinity and waterlogging is worse than either one alone (Barrett-Lennard, 1986), and only plants adapted to these conditions, such as sea barley grass (Hordeum marinum) will persist.

Water Authority plantation on the valley floor on a badly salt-affected site.

Australia is now celebrating the Decade of Land Care during which time increased emphasis will be placed on land conservation. Four articles in this issue of the Journal of Agriculture look at the role of trees in rehabilitating degraded land and water.

1 Supervising Research Officer, Hydrology and Land Use Research, Surface Water Branch

2 Research Officer, Soil and Vegetation Management Branch, Division of Resource Management
Where the land is highly saline or heavily grazed, scalds form which are prone to severe erosion.

**Groundwater system**

The groundwater system comprises shallow and deep aquifers. The shallow aquifer consists of coarse-textured surface soils which overly less permeable clays. A seasonal, perched water-table develops above the clay and water moves downslope.

The deep aquifer is based on the bedrock and consists of weathered materials. It can be recharged from above by water flowing through old root channels or fissures in the clay, or in gaps between particles of soil (especially in deep sands and gravels).

Studies have shown that the deep aquifer system carries only about 10 per cent of the water travelling underground, but is the major ‘source’ of salt coming to the surface. The shallow aquifer carries about 90 per cent of the water, but is generally of low salinity until water within it moves into areas made saline by the rising ‘deep’ groundwater.

**Reclamation philosophy**

The flow of saline groundwater to streams must be controlled if saline rivers and salt-affected areas on farms are to be reclaimed in the foreseeable future.

One way to minimize dryland salinity is to plant perennial, deep-rooted vegetation such as trees that can intercept and use large quantities of water.

An early design double-ridge mound plough. Soil is scooped up to form the elevated mound and a trough is pressed into the top of the mound. Seedlings are planted at the base of this trough.

The hydrologic systems associated with salinity in the high rainfall locations described in this article are often more complex than those of a simple sandplain seep (see 'Reclaiming sandplain seeps by planting trees' on page 18). Steeper slopes, the presence of dolerite dykes and areas of exposed and shallow bedrock complicate the movement of groundwater to saline seeps.

In the late 1970s, the Water Authority established plantations on catchments to determine how large a planted area, which tree species and what density of reforestation was necessary to control or lower groundwater levels.
How trees affect groundwater tables

Trees have often been described as 'pumps'. This description may be appealing when people talk about the effects of trees on groundwater levels, but it is not strictly correct, and in some cases may be misleading. Trees do not act like pumps. Pumps are designed to withdraw water of any quality from an aquifer at a set rate, and at any time. Trees do not behave like this, but they do have several desirable properties that affect the groundwater.

The behaviour of trees in relation to groundwater is shown schematically in Figure 2. Trees influence the watertable by reducing groundwater recharge and by using or transpiring (losing water from leaves to the atmosphere) groundwater.

Controlling groundwater recharge

Groundwater recharge is the movement of water from the atmosphere (rainfall) through the unsaturated soil zone to the groundwater. The greater the groundwater recharge, the more the watertable is likely to rise. Trees can reduce groundwater recharge by evaporation of water intercepted by the foliage, branches and stems before it reaches the ground, and by transpiration of soil water.

Interception loss is particularly significant for trees because of their large surface area. Eucalypts intercept from 10 to 25 per cent of rainfall.

Transpiration by trees reduces groundwater recharge by extracting water throughout the unsaturated zone. Water moves through the soil both as a broad front moving between soil particles, and through old root channels and other pipe-like structures.

Water flows slowly between soil particles. Trees, with their deep roots, are effective in taking up and transpiring this water, particularly during summer. Flow through pipe-like structures, such as old root channels, is relatively rapid and vegetation may be less effective in using this water before it recharges the groundwater.

The more water transpired from the unsaturated zone, the more rainfall it will take before recharge to groundwater occurs during the following season.

Annual crops and pastures are not as good as trees at extracting water from the unsaturated zone. Their shallow root systems are generally less than a metre deep and they cannot extract much water before the plants die in about November.

Groundwater use by trees

Trees can also influence groundwater tables by using the groundwater itself. Studies by CSIRO on the water-use of trees planted on and around groundwater discharge areas suggest that some species use the groundwater itself. This improves their growth rates and helps to lower watertables.
An often cited observation is that groundwater use by trees decreases with increasing groundwater salinity. Salts in water inhibit water absorption by roots.

Groundwater salinities of 10,000 mg/L TSS, less than the limit for stock water use, will not significantly lower the potential transpiration rate of most of the Eucalypt species commonly used for saltland reclamation.

Groundwater salinities above 30,000 mg/L TSS (sea water) will severely reduce the transpiration potential and growth rate of many eucalypts. These species may die if not enough fresher water is available above the groundwater.

Reforestation to control groundwater

The chosen tree species must be suitable for the site, ideally have multiple uses, and have a high water-use potential.

Suitability

We now have considerable information on tree species that are most suitable for given planting conditions. Consult the Departments of Agriculture, Conservation and Land Management, or your local Land Conservation District Committee for advice.

Western Australian scientists are studying the genetic variation of trees for their tolerance of waterlogged and saline conditions typical of saline seeps in the south-west. Cloning (a method of producing genetic identicals) of superior tree types is part of this programme.

Species identified so far for their tolerance of waterlogging and salinity include swamp sheoak (Casuarina obesa), salt river gum (Eucalyptus sargentii), river red gum (E. camaldulensis), swamp yate (E. occidentalis), swamp mallet (E. spathulata), York gum (E. loxophleba) and flooded gum (E. rudis).

A wide range of suitable species is available for well drained soils, away from saline seeps.

Multiple use

Multiple use refers to the other beneficial uses of trees, which may influence tree selection. Benefits include commercial tree cropping for timber, pulp, firewood or other products; shelter and shade; control of wind and water erosion; wildlife conservation and aesthetics. A plantation should always be designed with these other benefits in mind.

The Department of Conservation and Land Management is promoting commercial tree planting. Fast growing eucalypt plantations show considerable promise for pulpwood production (see 'Tree crops for profit and land improvement' on page 11). Wide-spaced pine agroforestry plantations have been shown to increase total farm productivity. More recent research on wide-spaced eucalypt agroforestry is also promising.

Water-use potential

Knowledge of the water-use capacity of tree species for a range of planting conditions would allow high water-use trees to be selected for the best control of groundwater levels. In this way, less agricultural land need be replanted to trees to control groundwater.

CSIRO has taken several measurements of tree water-use for farm plantations. These measurements have shown that trees can transpire up to three or four times the annual rainfall on a plantation. However, the results are not comprehensive enough to allow a confident ranking of species by water-use and site. In general, trees that grow well on a site are likely to use more water than poorly adapted species.
Planting methods

Best planting methods vary according to the site, so seek advice before starting. Preparation for tree planting can include deep ripping and herbicide spraying or scalping for pasture (weed) control. Scalping involves removing the topsoil to reduce the number of weed seeds.

In salty, waterlogged areas, research has shown that planting seedlings in a trough on two ridges (double ridge mounds) improves their survival and growth.

Other beneficial treatments for saline seeps include site drainage, mulching and use of large seedling containers. Added fertilizer is generally not useful in seepage areas with a history of moderate to high fertilizer applications. Young plants must be protected from rabbits.

Number of trees

Only a part of the farm land may need replanting to trees to control groundwater. This is because trees, particularly those planted on sites that stay moist into the summer, can transpire more rain than falls directly on the replanted area.

The Water Authority has developed a method to estimate the area needed to be replanted to trees. The area depends on the water-use of the tree species planted, the amount of remaining native forest, and the water-use and area of the agricultural plants grown. The area of planting required to lower water tables decreases with decreasing annual rainfall.

Based on current water-use data, the area of trees needed to lower the groundwater level by two metres in 10 years from the time of planting ranges from half of the cleared area of the farm at 1,200 mm/year rainfall to a third of the cleared area of the farm at 750 mm/year rainfall.

Planting smaller areas of cleared farm land may not result in as rapid or as large reductions in groundwater level. Increasing the production and water-use of the agricultural plants grown on the cleared area is expected to contribute to reductions in groundwater level, but as yet, this has not been demonstrated on a catchment.

A second method of determining the size of the reforestation area for salinity control is based on information on groundwater levels collected over 10 years at reforestation sites in the Collie and Mundaring catchments (Figure 3). The data suggest that about a quarter of cleared farm land would need to be replanted to trees to lower groundwaters by two metres over 10 years after planting.

Rainfall at the experimental sites within the Collie and Mundaring catchments over the measurement period (1978 to 1988) was 10 per cent less than the long term (1926 to 1988) average. If rainfall had been the long term average, we estimate that groundwater levels beneath pasture on the sites would, on average, have risen at a rate of 350 mm/year. In this case about 57 per cent of the cleared area would need to be reforested to lower the watertable by two metres in 10 years.
There is some confusion about the best location for tree plantations to lower groundwater levels. Some people advocate plantings on groundwater recharge areas (hilltops and slopes), others favour plantings on and surrounding discharge areas (lower slopes, valley floors and hillside seeps).

The evidence to date in Western Australia favours planting on and immediately upslope of discharge (seep) areas, providing groundwaters are not extremely saline (less than 30,000 mg/L TSS).

Whatever reforestation plan is adopted, it should be designed to meet specified objectives, of which groundwater control is often only one.

**Experimental evidence from various planting strategies**

Four partial reforestation strategies have been tested in the south-west of Western Australia for their ability to control groundwater levels.

They are:
- Plantations on lower slope and discharge zone.
- Plantations of widely spaced trees (about 200 trees per hectare).
- Strips or small blocks of trees strategically placed but covering a small proportion of the cleared area.
- Dense plantations (more than 600 trees per hectare) covering more than half of the cleared area.

Results from the various strategies are discussed briefly in this article. For further details on these sites, and the groundwater analysis, see Schofield et al. (1989).

**Plantations on lower slopes and discharge zone**

High density tree plantings on the lower slopes and discharge zone (saline seeps) have been tested at two sites. Only one of these sites, Stene's Valley Plantings (Figure 3), has enough records for analysis. At this site, 44 per cent of the catchment had been cleared

Figure 5. Comparisons of the yearly minimum groundwater levels in 1979 and 1988 across Stene's Valley planting site
for agriculture. In 1979, a third of the cleared area was planted to eucalypts. From 1979 to 1988, the groundwater beneath the trees was lowered by 2.0 m while under pasture the groundwater rose by 0.4 m (Figures 4 and 5).

**Plantations of widely spaced trees**

The effect of plantations of widely-spaced trees (about 200 trees per hectare) on groundwater levels has been investigated at three sites: Flynn’s Agroforestry, Stene’s Agroforestry and Boundain (Figure 3).

These sites represent a range of annual rainfall, tree species and planting densities. The Flynn’s and Stene’s sites have similar average rainfall (720 mm/year) whereas Boundain’s rainfall is about 450 mm/year.

The average groundwater changes under agroforestry compared to pasture are shown in Figures 4 and 5 (Stene’s) and Figure 6 (Boundain).

The results from Flynn’s are similar to those from Stene’s. At each site agroforestry has lowered the groundwater significantly relative to pasture. However, at the Flynn’s and Stene’s sites, the lowering of the groundwater relative to pasture has halted, suggesting a new recharge-discharge balance may have been reached. Thus wide-spaced agroforestry (by itself) appears to be better suited to lower rainfall areas as a groundwater control strategy.

**Strips or small blocks of trees**

Strategic plantings of strips or blocks of trees which cover only a small percentage of cleared land have been studied at three sites: Flynn’s Landscape, Stene’s Strip and Bannister (Figure 3). In each case tree plantings have had little or no effect on groundwater levels. Thus in areas with annual rainfall greater than 700 mm, planting less than 15 per cent of cleared farm land to trees is unlikely to have a significant impact on groundwater (Figure 5).

**Dense, extensive plantations**

Dense plantings of more than 600 trees per hectare that cover over half of previously cleared farm land have been investigated at two sites, Flynn’s Hillslope and Stene’s Arboretum (Figure 3).

At Flynn’s Hillslope the whole site had been cleared for agriculture and 54 per cent of it was replanted to trees. Groundwater beneath the trees was lowered by 2.8 m from 1979 to 1988, while there was a slight lowering (0.5 m) of the groundwater beneath the pasture over the same period.

At Stene’s Arboretum about 70 per cent of the farm land was successfully replanted with trees. Groundwater beneath the plantings was lowered by 5.6 m from 1979 to 1988 while under pasture the groundwater rose by 0.4 m (Figure 3).

**Will the trees become ‘salted out’?**

There is some concern about the potential for increased salt concentration under valley floor plantations and the long term effect on the trees.

![Figure 6. Groundwater response to plantations of widely-spaced trees at Boundain:](image-url)

(a) comparison of groundwater levels across the site between 1981 and 1988;

(b) annual rainfall and groundwater level variations beneath pasture and plantations. (Data supplied by Ric Engel, Department of Agriculture).
At all sites with more than 700 mm of rainfall a year, groundwater salinities have decreased over the monitoring period and there has been no major build-up of salt in the soil profile. Thus, in these areas tree planting should be a long term solution to salinity control.

At the Boundain site (450 mm/year rainfall), groundwater salinities have, on average, increased; soil salt concentrations have decreased in the depth range 0 m to 0.75 m, increased in the depth range 0.75 m to 2.25 m, and remained the same beneath 2.25 m. Thus conditions near the surface for trees and other plants have become more favourable, with lower soil salt and less waterlogging.

On this basis the wide-spaced agroforestry plantations in lower rainfall areas should also be an effective long term salinity control measure.

### Promising tree planting strategies

- Plantations of widely spaced trees (about 200 trees per hectare) have lowered the groundwater beneath the trees by 1.0 m to 1.5 m relative to groundwater levels below pasture, but in two of the three experimental sites the lowering has stopped.
- At this stage we are not certain whether the area and density of these plantings in areas receiving more than 700 mm of rain a year are adequate to eliminate groundwater discharge to streams. However, there is evidence that widely-spaced plantings will be effective in lower rainfall areas.

- Trees planted on the lower slopes and discharge zone have lowered the groundwater level by 2.4 m relative to the level beneath pasture at the one site studied. The continuing downward trend in the groundwater at this site indicates that this valley planting strategy has considerable promise for the control of stream and land salinity.

- Dense, extensive tree plantations (more than 600 trees per hectare on at least half of the cleared land) are the most effective strategy for lowering the groundwater level in locations with more than 700 mm of rain a year. However, this strategy will only be useful if landholders consider commercial tree plantings an appropriate use of their land.

- Strategically placed strips or blocks of trees which cover less than 15 per cent of cleared farm land are not successful in controlling saline groundwater in areas with more than 700 mm of rain a year. They could be effective in low rainfall areas, but this has not been tested.