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PLANT BASED SOLUTIONS FOR DRYLAND SALINITY MANAGEMENT

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Abstract

Plant based options for the prevention and management of dryland salinity, particularly within recharge areas, are examined. The use of deep-rooted perennial vegetation (trees and pastures) can increase water use within the landscape, helping to control the spread of dryland salinity. However, catchment characteristics can strongly influence the effectiveness of plant based options for controlling salinity, especially in the short term. Plant based options that reduce groundwater recharge are detailed and conditions that maximise their effectiveness described.

Background

Increased salinisation can be linked directly with the loss of hydrologic equilibrium caused by vegetation clearing and changes in land use. This link between clearing and the movement of salt is well-documented (Martin & Metcalfe 1998, Agriculture Western Australia, 1999a, MDBC 1999). The NSW Salinity Strategy recognises the management of native vegetation and salinity to be complementary, and that to "slow down the increase in salinity, we need to protect and manage our vegetation" (NSW Government, 2000).

Each year, trees are planted with the intention of controlling rising watertables. It is assumed that taking trees away caused the problem so putting them back will fix it. But can trees and other types of perennial vegetation such as pastures save our catchments? With this question in mind, plant based options that reduce recharge to groundwater were examined. The social and economic implications of implementing plant-based solutions are, however, not discussed, nor are other options such as engineering solutions, making better use of land affected by salt or learning to live with salt.

The results were mixed. The effectiveness of plant based solutions was found to be governed by many factors, including hydrogeology, location of plantings within the landscape, the proportion of vegetation cleared and revegetated, the density and configuration of plantings, species type, climate (annual rainfall & evaporation), watertable salinity and soil type. Their implementation is also complicated by the following factors.

- The Australian landscape houses vast stores of salt which has accumulated in the soil profile. Rising watertables dissolve this salt, transferring it to discharge areas.

- Native vegetation, adapted to Australia's highly variable climate, uses water when it is available, including that which is stored deep in the soil (JVAP, 2000).

- The scale of management intervention varies from local to large catchments (ie. from less than 1 km^2 to 1000's of km^2).

- Catchments are heterogeneous in terms of vegetation, soils, slope and basement rock formation. This leads to wide variability in recharge and discharge rates across the landscape. This heterogeneity also results in large variation in the amount of salt stored across the landscape.

- Hydrologic processes operate over varying time-scales, from short duration storm events to long duration groundwater responses (100's to 1000's of years).

The use of deep-rooted perennial vegetation, particularly within recharge areas, can increase water use within the landscape and reduce recharge of groundwater. Land management practices that reduce recharge of groundwater include:

1. Protecting and managing the remaining remnant vegetation, including native perennial pastures, particularly in the upper catchment areas as well as in salt prone areas – this is our first line of defence against the development and spread of dryland salinity.

2. Re-establishing deep-rooted perennial species, targeting high recharge areas.

3. Integrating agroforestry with farming practices.

4. Replacing annual pastures with perennial pastures.

5. Modifying cropping practices to increase water use of crops and pastures.

In those areas where plant based options are neither suitable nor appropriate, other options such as engineering solutions (e.g. installing pumping and drainage works), making better use of land affected by salt or learning to live with salt may be more appropriate.

Using trees and shrubs to reduce groundwater recharge

Native trees and shrubs are effective water users. The deep roots of perennial plants, especially the longer-lived woody shrubs and trees (and some perennial forage species such as lucerne) have the ability to use water stored deep in the soil profile (Raper, 1998, Taylor *et al* 1998). They are opportunistic users of water, and are able to continue transpiring once annual pastures have aged and crops have been harvested (Eastham *et al*, 1993, Bulman, 1995).

Tree and shrub planting in recharge areas to reduce recharge to groundwater has been attempted with varying degrees of success (Farrington & Salama 1996, Salama *et al*, 1999, Schofield *et al*, 1989). Successful case studies are detailed in Marcar & Crawford (1996), Bell (1999), Schofield and Bari (1990), Schofield (1990), Greenwood (1991), Farrington and Salama (1996), George *et al* (1999a & b), and Thorburn and George, (1999).

Although direct uptake of groundwater by vegetation is not well documented (Farrington & Salama 1996, Thorburn and George, 1999), evidence from research in Western Australia indicates that trees can lower watertables under a wide range of landscape conditions (Schofield *et al* 1989, Stolte *et al*, 1997, Raper 1998). However, watertable responses have not occurred at every site where trees have been planted. The magnitude of the response has also varied. Reports of watertable reductions of up to 6 metres contrast with reports of watertable rise, despite revegetation (Schofield *et al* 1989, Greenwood *et al* 1985). Although the reasons for these variations were not reported, factors such as climate could have influenced results.

Although the watertable response to revegetation is governed by many factors, a review of the literature found that, in general, trees have the greatest potential for lowering watertables where:

- ❖ Species selected are salt and waterlogging tolerant. Salt sensitive trees do not perform well on sites with high soil salinity and it is unlikely that significant water use will occur on such sites.

- ❖ Groundwater salinity is relatively low. The magnitude and rate of watertable reduction is likely to be greater for fresher groundwater (<7.5 dS/m) than for moderately saline groundwater (<15 dS/m). Minor reductions may occur at higher salinity levels. Generally, trees planted on very saline and shallow watertables cannot tolerate saline water. This can limit their application to the treatment of dryland salinity.

- ❖ Watertables are between 3 and 5 m deep. If shallower, root zone salting will limit tree water use.

- ❖ Roots can extend close to the watertable.

In addition, a search of the literature indicated that:

- ❖ Trees planted on soils with very high saturated hydraulic conductivities (e.g. very coarse sands) or very low saturated hydraulic conductivities (clays) have little effect on watertable levels.

- ❖ Trees planted on thin (<5-10 m) mostly unconfined aquifers (water moves freely in and out of the system) with shallow watertables can significantly reduce the extent and severity of groundwater flow through to seeps. On the other hand, trees that are planted on deep (>10-20 m) aquifers with shallow watertables will not significantly reduce groundwater flow through to seeps (Thorburn & George, 1999).

To maximise the effectiveness of trees and shrubs in reducing recharge to groundwater it is recommended that:

- ❖ Planting occur on the recharge areas of local aquifer systems.

- ❖ Plantings occur where the country is steep and dissected, characterised by weathered and fractured rock with shallow soils (less than 5 m) or where the soils are deep, sandy and permeable (National Land and Water Resources Audit, 2000).

- ❖ Plantings be located in areas with access to relatively fresh groundwater (George *et al*, 1999a&b).

- ❖ The impact of climate is considered - the amount of rainfall, its distribution, the sequence of rainfall events and seasonality influence recharge rates. Most dryland salinity occurs in the 400 to 600 mm/yr rainfall zone. The choice of species and economical viability of tree planting within this rainfall zone can be limited. Within the 400 to 550mm/yr rainfall zone, for example, perennial pastures can be effective in reducing recharge, but are less effective in winter dominant rainfall zones with greater than 600mm/yr (Commonwealth of Australia, 2001).

- ❖ Species with high water uptake are used.

- ❖ Trees and shrubs be planted in configurations to maximise water usage while minimising the area planted to trees (Agriculture Western Australia, 1999b). Densely planted woodlots for example, strategically located in recharge areas, may be appropriate on farms.

- ❖ Small plantings be strategically located (e.g interception belts on perched aquifers). Small, localised plantings, selected without knowledge of the surface and groundwater systems operating are unlikely to reclaim saline areas or prevent its spread (Farrington & Salama, 1996).

- ❖ Within intermediate and regional scale systems extensive areas be revegetated. This can be anywhere between 30 and 50% of the landscape.

- ❖ If trees are planted in discharge zones choose those areas where the groundwater salinity is less than 7.5 dS/m (Francis & Sonter, 1994), the site has a relatively shallow local groundwater system. Plantings should take place on the lower slopes above or away from seeps and/or scalds and management techniques should be used to assist in the establishment of plant cover (e.g. fencing to control grazing, mulching and fertilisation).

Prior to the planting of trees and shrubs it is important to determine whether or not it is the most appropriate solution for that particular landscape. This requires consideration of recharge rates across the catchment and the salinity of the groundwater within that catchment. It also requires consideration of the social and economic implications of implementing tree and shrub planting, particularly if extensive plantings are required.

If the planting of trees and shrubs is considered suitable, determine:

- The best place to plant for maximum effect. Plantings must be well planned and strategically located (recharge zones) if they are to have the desired effect (Australian Landcare, 2000). For example, within Western Australia, the relationship between the decline in watertable depth and the location (or landscape position) of revegetation was investigated by George *et al* (1999b) at 33 revegetated sites. The magnitude of watertable response was found to increase as trees were located further upslope from the valley floors and lower slopes.

- The minimum planted area required to control salinity and the time scale for realising the benefits. This requires consideration of the scale of the groundwater system (local, intermediate or regional) (JVAP, 2000).

- How tree and shrub planting can best be combined with other vegetation/agronomic and engineering measures.

- Whether or not the planting can be designed to meet other objectives such as biodiversity conservation or carbon sequestration for reduction in greenhouse gas emissions.

Using crops, annual and perennial pastures to reduce groundwater recharge

Crops, annual and perennial pastures are acknowledged as an essential part of Australian agriculture. It is recognised that many current agricultural methods are encouraging the spread of dryland salinity. “Leakage” under current and modified farming systems is likely to be inevitable (Walker, 1999). The question is, how much “leakage” can be tolerated on-site or off-site to maintain ecological services and agricultural production. This is the subject of investigation by CSIRO and the Department of Land and Water Conservation (DLWC). Research has shown that there are many options that reduce “leakage” and increase water use in the agricultural landscape, options that maintain economic returns while assisting recharge control (Stirzaker, *et al.*, 2000, Centre for Natural Resources, undated and Clifton, undated). To assist in the reduction of watertables, farming practices can be modified to:

- Incorporate farm forestry into existing farming systems.

- Incorporate alley farming where trees can be grown in laneways or alleys with crops and pastures grown in the inter-alleys (Blumenthal and Young, undated).

- Increase the area sown to perennial pastures.

- Alternate or mix together pastures and crops to maintain reasonably constant water use (e.g. phase farming), to minimise fallowing.

- include the use of perennial pastures (eg lucerne) in alleys of an intercropping system, with annual crops grown in the inter-alleys (intercropping) (Centre of Natural Resources, undated, JVAP, 2000).

- Utilise new agricultural plants (Stirzaker *et al.*, 2000).

Perennial pastures can be established in recharge areas that are not heavily planted with trees and shrubs. Such areas can include ridgelines or where shallow soils of low water holding capacity overlie fractured rock. They can also be established in areas where soil erosion is of concern and where groundcover is needed. Perennial pastures generally have higher water use characteristics than annual pastures and crops (Commonwealth of Australia, 2001). Some perennial pastures, such as lucerne, can have similar water use patterns to trees (Stirzaker & Lefroy, 1997). Combinations of cool and warm season species can be used to ensure year round water consumption (Jones, 2000).

Planting a blend of perennials and annuals will enable landholders to graze or cultivate while increasing water use. Annual crops and pastures can be planted in those areas where the bedrock or watertable is too shallow for perennial pastures and trees, or where rainfall is inadequate for growing perennials (Wentz, 1997).

Traditional methods of farming can be manipulated and new agricultural technologies applied to increase water use. Small increases in water use over large areas can substantially reduce recharge to groundwater. Alternative farming practices that reduce recharge include: alley farming or cropping, phase farming, intercropping, new agricultural plants and opportunity cropping. While these practices are relatively new and untrialled in large-scale environments, overtime, their suitability to different environments make them an attractive management option to control salinity. In terms of recharge control, continuous cropping is the least favoured, and fallowing is a very undesirable management practice for salinity control.

The influence of groundwater systems on the selection of plant based options

Understanding how landscapes and groundwater processes function to cause salinity will aid selection of the most appropriate plant based option. Local systems provide the greatest opportunity for farm-based catchment management aimed at dryland salinity mitigation. Such systems are fully contained within small catchments, have easily identified discharge zones, and require a relatively small number of landholders to adopt alternative management practices (Coram *et al*, 1999).

Some local groundwater flow systems have a high capacity to transmit water through an aquifer. In such catchments, the long-term salinity risk is lower and the responsiveness to tree planting greater (Hatton & George, 2000). In these catchments JVAP (2000) recommends alley farming, tree belts and widely scattered trees. Local groundwater systems can also have low flows. The response to revegetation in these systems will be slow (Hatton & George,

2000) and extensive recharge control is required. Within these systems closely-spaced alley farms or phase farming with perennial high water use crops and/or pastures with or without trees planted over most of the catchment can be effective.

The scale at which intermediate flow systems operate creates difficulties for farm-based catchment management programs (Coram *et al* 1999). To reduce discharge of saline water in intermediate flow system catchments, significant proportions of the landscape will need to be replanted, often beyond what is practical (socially and economically) or what can be achieved. To be effective in reducing recharge, as much as 30-50% (sometimes more) of a catchment may need to be planted with trees, shrubs and/or perennial pastures. Where watertables are still deep, limited revegetation may buy time, but probably will not avoid widespread salinisation of the catchment (Hatton & George, 2000). JVAP (2000) recommends alley farming with closely spaced trees combined with perennial pasture as well as engineering strategies such as deep surface drains.

Regional systems occur on a scale that is so large that it makes farm based catchment management options ineffective. Within these systems, dryland salinity mitigation usually involves engineering measures to protect high value assets and infrastructure, together with the adoption of “living with salt” strategies (Coram *et al*, 1999).

Limitations of plant based options

Although plant based options to control recharge of groundwaters are both attractive and sustainable, they can be difficult to implement, the reasons being that:

1. Recharge areas are difficult to define.

2. It is difficult to predict salinisation risks and appropriate management options in unstudied catchments. Often, management options implemented in a particular catchment are based on demonstration sites from other areas that bear no physical resemblance to local conditions. (Coram, 1998).

3. The scale of the processes controlling groundwater rise are frequently much broader than can be addressed by local actions.

4. Extensive replanting of recharge areas with deep-rooted perennial vegetation can be required to significantly reduce the amount of water reaching the groundwater system. Although large-scale revegetation will reduce recharge to groundwater, at a catchment scale, the effects may not be felt for decades or even hundreds of years (Heaney & Beare, 2000, Herron *et al*, 2001b).

5. Vegetation options, like other management options, take time to influence salinisation rates.

6. Recharge areas are often distant from areas of land and water salinisation. This means that the areas that need planting are often managed by landholders who do not suffer the effects of salinisation (Coram, 1998).

7. Establishing trees can be expensive. It can be 25 years before there is an economic return. Although farm forestry is being encouraged in Australia, adoption is slow because farming with annual species is considered to be more profitable (Stirzaker & Lefroy, 1997).

In addition, planting trees to reduce salt loads to streams can come at the expense of flow reductions. Tree planting or changing the surface cover from crops to trees and shrubs can, in some catchments, lead to a reduction in streamflow, a result of reduced runoff. This is however most likely to occur in high rainfall zone catchments (Hatton & George, 2000) where salinity is less likely to be a problem.

Current work

To effectively implement plant-based solutions, identification of recharge areas is required. A GIS based approach to recharge mapping, with validation against discharge mapping, is currently being undertaken by DLWC with results expected in December 2001.

To improve prediction of the effect of land-use strategies on salinity, DLWC has developed a suite of models to:

- evaluate where dryland salinity is currently occurring in the landscape
- predict the impacts of land use changes on run-off, salinities and salt loads from catchments and the contributions of these changes to meeting within valley and end of valley targets.

PERFECT has been adapted by the department to model the impacts of vegetation changes on recharge at a given location. FLAG (Fuzzy Logic Analysis GIS) has been used to identify discharge sites while CATSALT (Catchment Scale Salt Balance Model) provides an integrated overview of water and salt movement across the landscape. For example, using CATSALT, CNR examined the impacts of different levels of tree planting in the Kyeamba Valley, NSW. Reafforestation of 50% of the valley was predicted to almost halve the annual flow and salt load from the catchment. (Tuteja *et al.* 2001).

Future work aims to “optimise” the location of “green pumps” across the landscape with a focus on identification of high recharge sites. If approved, the project will commence next financial year.

Conclusion

To reduce recharge to groundwater, management options should be tailored to the prevailing conditions in the landscape (e.g. scale of the groundwater system, social and economic conditions). The overall landscape must be managed rather than just selected elements. Approaches that address only the symptoms (e.g. tree planting in discharge areas) are more likely to fail, particularly if the processes driving hydrologic disequilibrium are allowed to continue.

Although groundwater recharge is generally more concentrated in certain areas of a catchment (recharge zones), at some level, the whole catchment will contribute to recharge. Long-term solutions will therefore need to involve the whole catchment area and encompass the range of issues arising from changes to the water cycle, of which dryland salinisation is but one.

Concentrating on just one aspect, such as replanting trees, particularly in intermediate and regional scale systems, is unlikely to succeed in controlling groundwater recharge within a time frame helpful to the community. There is no one solution, and, in practice, combinations of the options described earlier will be required. These combinations will vary for each catchment and landscape type. Plant based options will need to combine with other options such as engineering solutions, making better use of the land affected by salt, and living with salt.

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