Targeting strategic tree and perennial pasture planting to reduce stream salinity in the Warren River Recovery Catchment

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Abstract

The Warren River was identified by the Government of Western Australia as a potential water resource for the south-west. In order to reduce stream salinity to potable standards, tree and perennial pasture plantings have been promoted to lower the groundwater table and decrease the salt load inputs. Multiple land-use change scenarios were created following the guidelines of mixed tree and perennial pasture plantings, targeting high salt load Response Units in low rainfall zones were modelled using the LUCICAT model. Tree plantings were shown to be more effective than perennial pasture planting in reducing stream salinity in the Warren Catchment. Summer active perennial pasture plantings increase stream salinity due to the reduction in transpiration during the dominant winter rainfall period in the SWWA resulting in greater runoff and salt load inputs into the river. Strategic tree and perennial pasture plantings are not likely to achieve the goal of reducing stream salinity to potable standards by 2030 in the Warren Catchment without the intervention of a hard engineered approach.

1. Introduction

The Warren River is the third largest river in the south-west of Western Australia (SWWA) with a streamflow capacity equal to 250GL/yr (Mayer, Ruprecht, & Bari, 2005). The Government of Western Australia identified the Warren River Catchment as a potential future water resource for the south coast of Western Australia, assigning the Department of Water as lead organisation in a cooperative effort to reduce stream salinity to potable standards, 500mg/L TDS, by 2030. The project objective was to model tree and perennial pasture planting scenarios in the LUCICAT model in the aim of reducing stream salinity to potable standards by 2030.

1.1 Salinity

The removal of native deep rooted vegetation for shallow rooted agricultural crops has been proposed as the primary cause of dryland salinity (Williamson *et al.*, 1987). The removal of trees the amount of transpiration and interception are reduced resulting in increases in runoff and groundwater recharge (Clarke *et al.*, 2002; Nulsen *et al.*, 1986) (Figure 1). Stream salinity results from interception of saline groundwater entering streams and lakes and the removal of salt washed from the soil surface by runoff. Stream salinity has been an issue in Western Australia for the last century since saline water was reported to have increased in the Mundaring Reservoir (Reynoldson, 1909). Currently more than half of the major rivers in the SWWA were reported brackish to saline (Mayer *et al.*, 2005). By replanting shallow rooted crops or cleared areas with deep rooted vegetation it is hoped the water balance will revert back to the conditions and levels prior to clearing (van Dijk *et al.*, 2007).

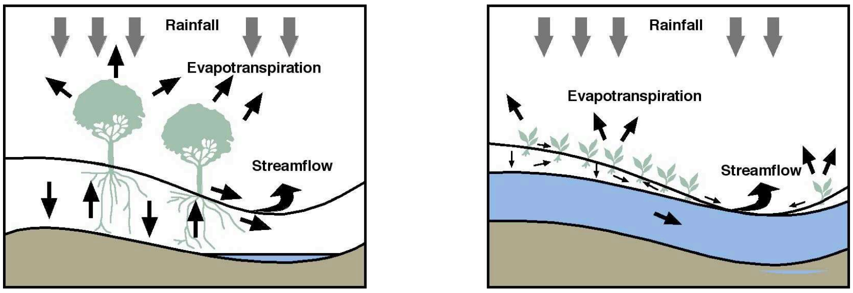

Figure 1 Water balance changes from clearing of native vegetation (Government of Western Australia, 1996)

1.2 LUCICAT

The Land Use Incorporated Change CATchment (LUCICAT) model, a conceptual hydrological model, was used to predict the impact of land-use change on daily streamflow and salinity. As a conceptual model, the LUCICAT model structure, parameters and inputs are known *a priori*, with the parameters calibrated to observed rainfall, streamflow and salinity. The model uses a downward approach with increasing complexity at ever increasing smaller scales (Bari, 2005).

2. Catchment Description

The Warren River Catchment in the SWWA, 300km south-east of Perth covers an area of 4350km^2 (Mayer *et al.*, 2005). The catchment contains the towns of Pemberton and Manjimup with Kojonup to the north of the top end of the catchment. The mean annual rainfall ranges between 600mm and 1200mm from the north to the south of the catchment. The Warren River is fed by four main tributaries: Tone, Wilgarup, Perup and Dombakup rivers. The mean annual flow for the Warren River at the Barker Road Crossing gauging station is 291GL with a stream salinity of 895mg/L TDS (Smith *et al.*, 2006). The cleared area was calculated at a maximum of 33% in 1980, but due to extensive plantations since 1990 the cleared area in the catchment has decreased to 19% in 2006.

3. Methodology

The LUCICAT Live framework uses a Geographic Information System (GIS) interface that allows the data to be represented spatially. Three spatial input datasets are required by the LUCICAT model namely the attribute, channel links and channel nodes shapefiles. The attribute file contains the spatial location and features of the Response Units (RUs) or hydrological sub-catchments. The RUs, delineated from a Digital Elevation Model (DEM), were aggregated to a larger scale of Management Units (MUs) for the reporting of results. The vegetation file defines the land-use history of the catchment as it is designed to accommodate seven different vegetation types within each RU namely native forest, annual pasture, reforested woodland, pine woodland and three types of perennial pastures (Bari *et al.*, 2009). Response Units are divided into Functional Units each with one or more Land-use Units that can change over time. Ten LANDSAT images were used to identify the land-use between the years 1988 and 2007.

3.1 Land-use Scenarios

Multiple land-use change scenarios were created following the guidelines of mixed tree and perennial pasture plantings, targeting high salt load RUs above the 600mm rainfall isohyet.

This aimed to maximise the effectiveness of reduction in stream salinity concentrations. The high (>2500kg/ha) and medium (>1500kg/ha) salt load regions were identified from previous applications of the model for the Base Case scenario shown in Figure 2.

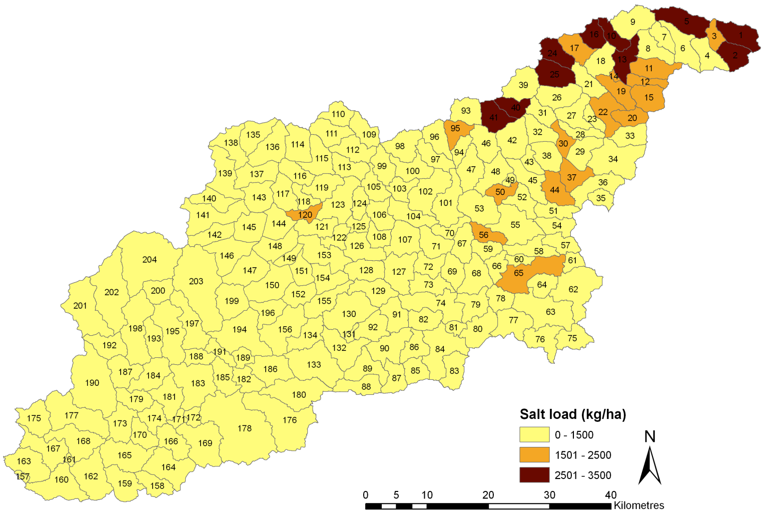

Figure 2 Classification of Response Unit salt load outputs

The land-use scenarios are described in Table 1. Land-use scenario A is a blanket approach used as a comparison for the strategic approaches. Land-use scenarios B to G focus plantings in RUs with salt loads greater than 2500kg/ha. Land-use scenarios H and I focus plantings in RUs with salt loads greater than 2500kg/ha and in RUs with salt loads greater than 1500kg/ha located in the low rainfall zone (less than 600mm annually). Group A are the RUs with high salt loads while Group B consists of medium and high salt load RUs. The reforested rooting depth was initially set at 4.5m in 2008 increasing to a maximum depth of 15m by 2015. The perennial pasture (summer active) rooting depth was initially set at 1.5m in 2008 increasing to a maximum depth of 4.5m by 2015. All scenarios used Leaf Area Index (LAI) values of 1.2.

Scenario	*Description*	*Location (RUs)*
Base case	Maintain 2007 vegetation	Entire catchment
Land-use A	Cleared area replanted with trees (100%)	Entire catchment
Land-use B	Cleared area replanted with trees (100%)	Group A
Land-use C	Cleared area replanted with trees (50%)	Group A
Land-use D	Cleared area replanted with perennial pasture (100%)	Group A
Land-use E	Cleared area replanted with perennial pasture (50%)	Group A
Land-use F	Cleared area replanted with trees (50%) and perennial pasture (50%)	Group A
Land-use G	Cleared area replanted with trees (30%) and perennial pasture (30%)	Group A
Land-use H	Cleared area replanted with trees (50%) and perennial pasture (50%)	Group B
Land-use I	Cleared area replanted with trees (30%) and perennial pasture (30%)	Group B

Table 1 Land-use scenario planting descriptions and locations

4. Results and Discussion

All scenarios reduce streamflow and salinity from the observed values of 250GL and 895mg/L TDS measured between 1990 and 2001. Land-use scenario A (blanket scenario) results in the largest reduction of streamflow and salinity. It is also the only scenario that achieves the target reduction of 500mg/L TDS by 2030. Land-use scenarios B and C follow almost identical trends in the reduction of stream salinity (Figure 3). An additional increase of 50% deep rooted trees in Land-use B has no impact on the salt load or streamflow.

Scenario	*Affected area (km^2)*	Streamflow (GL)	Salt load (kg/ha)	Salinity (mg/L TDS)
Base Case	-	235	170	724
Land-use A	962	193	81	420
Land-use B	115	231	148	640
Land-use C	58	232	148	639
Land-use D	115	233	161	688
Land-use E	58	242	204	844
Land-use F	115	231	148	640
Land-use G	69	237	163	688
Land-use H	234	227	129	568
Land-use I	140	238	156	657

Table 2 Streamflow and salinity at Barker Road for land-use scenarios

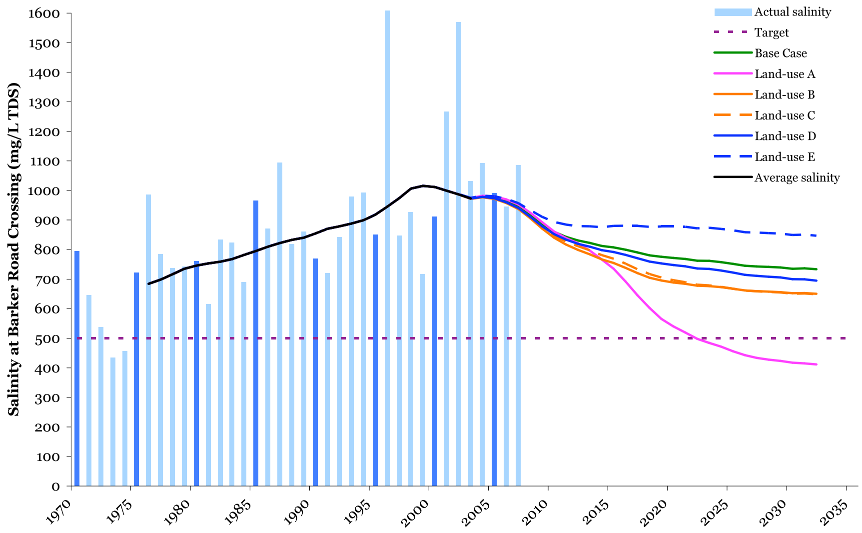

Figure 3 Average stream salinity at Barker Road Crossing for non-mixed land-use scenarios

Land-use E is the only scenario resulting in greater stream salinity than the Base Case. The stream salinity concentration increased due to the removal of water supply without any significant reductions in salt load. The explicit use of summer active perennial pastures in the upper catchment (Land-use E) would have a negative impact on stream salinity unless significantly more land is dedicated to perennial pasture plantings. Although the blanket approach (Land-use A) reduces the stream salinity by a greater proportion, strategic plantings are highly effective in reducing the stream salinity of the Warren River. Stream salinities are further reduced by extending the plantings to medium salt load regions (Figure 2) as in Land-use scenarios H and I (Figure 4). Land-use H and I doubles the cleared area planted in Land-use F and G respectively. The stream salinity is responsive to plantings in medium salt load regions as Land-use H and I show differences of almost twice that between Land-use F and G and the Base Case.

Tree planting in Western Australia has been shown to only have localised impacts on groundwater levels with little or no effect more than 10-30m from the planted area (George *et al.*, 1999). This significantly reduces the effect trees have on groundwater in situations where trees intercept lateral flow. Tree competition for water reduces the carrying capacity of annual and perennial pasture and reduces the clean wool production per hectare on annual pastures (Sanford *et al.*, 2003). Although the tree planting scenarios were focused in the low rainfall zone, they may also prove to be effective in the higher rainfall Wilgarup MU. By placing plantings in the Wilgarup MU, which produces significant amounts of salt load with limited proportions of runoff , reductions in stream salinity concentration can be maximised.

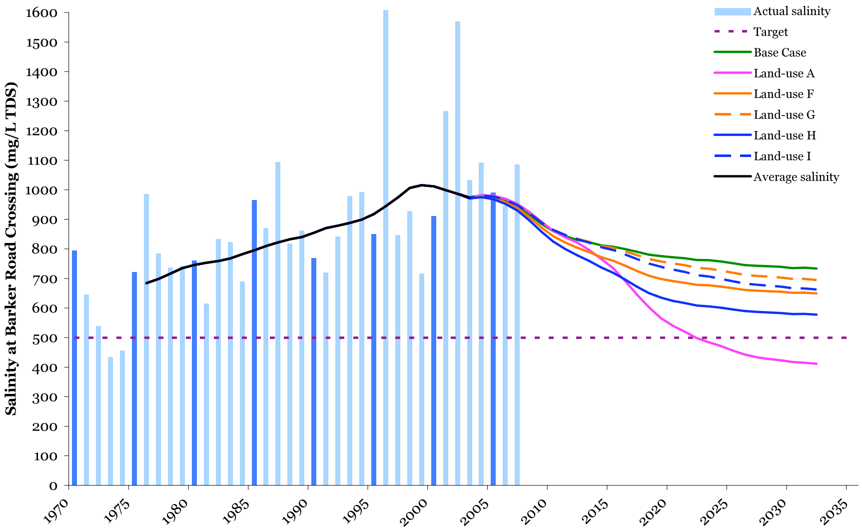

Figure 4 **Average stream salinity at Barker Road Crossing for mixed land-use scenarios**

Land-use D is able to reduce the amount of streamflow and salinity in the Warren River, however, the trend is reversed when the much lower perennial pasture planting percentage scenario of Land-use E is employed. Although studies have found that perennial pastures increase the soil water deficits (McDowall *et al.*, 2003, Sanford *et al.*, 2003), the findings in this project are consistent with George et al. (1999) in that at least 70 to 80 percent of the landscape will need to be planted if perennial pasture is to significantly reduce recharge.

The increase in streamflow and salinity observed under the perennial pasture planting scenarios may be due to the use of water during the dry season for summer active perennial pasture, resulting in a greater degree of runoff and salt load inputs during the wetter rainfall periods in winter. As this is the dominant period of salt load injection into the river, the summer active perennials are unable to transpire the water aiding in supplying load to the river. A winter active perennial pasture could be used to reduce the runoff and discharge but this would reduce the productivity of the land as a food crop is replaced with a potentially less profitable and redundant feed source while a summer food source is still required for stock. A potential farming practise of “pasture cropping” is to seed annual pastures into the perennials that will allow water to be taken up in the winter from the annuals while perennials provide green feed for stock in the summer.

5. Conclusions & Future Work

Deep rooted tree plantings are effective in reducing groundwater levels and stream salinity in the Warren River Catchment. By strategically planting trees in high and medium salt load regions, stream salinity can effectively be reduced. Summer active perennial pasture, whilst reducing the streamflow, has minimal impact on salt load reductions. This is primarily attributed to summer active perennials being dormant in the wet season resulting in increased runoff and salt load inputs. Land-owners may profitably benefit from the use of perennial pastures but their application at small scales (<70% or 80%) will negatively affect salinity concentrations in the Warren River. Further research into the impact of pasture cropping is necessary to understand its impact on catchment hydrology and effectiveness in reducing stream salinity.

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