Targeting land-use change to lower recharge to groundwater in dry environments

Brendan Christy[1,2], **Garry O'Leary**[3], **Craig Beverly**[2,4], **Muhuddin Anwar**[3], **Mark Hocking**[5], **Joanne McNeil**[6], **Brett Bryan**[7]

[1] Department of Primary Industries, Rutherglen, VIC
[2] CRC for Plant based Management of Dryland Salinity, Rutherglen, VIC
[3] Department of Primary Industries, Horsham, VIC
[4] Department of Sustainability and Environment, Rutherglen, VIC
[5] Hocking et al. Pty Ltd, Bendigo, VIC
[6] Department of Primary Industries, Bendigo, VIC
[7] CSIRO Land and Water, Adelaide, SA

Introduction

Significant land use changes have been considered necessary to reduce the impact of farming practices that leak water into the saline groundwater system in the Wimmera and Mallee regions of north-west Victoria, Australia (Wimmera regional Salinity Action plan 2005-2010, Mallee regional Catchment Strategy 2003-2008). These regional catchment management plans have set targets to reduce groundwater accessions from land which in this region focuses on the shallow Parilla sand aquifer that conducts groundwater movement from the Wimmera and Mallee to the river Murray.

The modelling application discussed in this paper considers how one of the Resource Condition Target's (RCT), namely a 20% recharge reduction from farming systems can be achieved. There will be an infinite number of combinations that could achieve this target, because it is rather broad in terms of where to change landuse. Another RCT is to reduce the area of salinised land from 10 to 8%, and the question arises can these both be met? It is easy to envisage reducing recharge by 20% as an average over the whole region, without reducing salinisation at all, because landuse change is targeted in watertable unresponsive areas.

The Catchment Analysis Tool (CAT) landscape modelling toolkit (Weeks *et al.* 2008) was employed to study alternative landuse scenarios, because it links drainage from the root-zone to groundwater and surface water interactions. The advantage of CAT is that it can explicitly model surface and groundwater processes within the landscape (Beverly *et al.* 2005). This connectivity of CAT offers a more realistic understanding of likely responses of dryland salinity and watertable related management options than just employing single enterprise models.

Materials and Methods

The area of study in this region focused on the farming land, although modelled results generated covered both this area and the publicly owned native vegetations areas covered by State and National Parks. Large annual rainfall gradients from less than 290 mm to over 660 mm exist across both regions. This means that landuse change applied randomly to reduce recharge by a fixed amount will best be applied at the wetter ends, possibly with little effect on the rivers and low lying areas in the drier parts. We therefore divide the region into eight rainfall zones (Figure 1).

The cropping systems model in CAT simulated the current cropping and grazing practice across the Wimmera and Mallee. A 44-year simulation was made so that temporal behaviour of the daily water balance was clear. The simulation was done to maintain connectivity in the underlying Parilla sand aquifer to the river Murray. Lucerne was chosen as a representative perennial crop to replace current annual cropping and pasture rotations. Other perennial vegetation e.g. trees or agroforestry would equally be applicable. Various levels of adoption of lucerne were determined from zero to 100% of the agricultural land area and the impact of changing to this perennial land use on recharge was determined.

Two scenarios were modelled. The first (Scenario 1) considered an untargeted random

Lucerne adoption strategy across the whole of the cropping and pasture area overlying the Parilla sand aquifer. The aim was to reduce recharge by 20%, irrespective of the proximity to the watertable or the Murray or Wimmera rivers across eight rainfall zones. The second (Scenario 2) had the same objective as above, that is to prevent the same volume of water as recharge (167,769 ML) from reaching the watertable to effect an equivalent 20% recharge reduction, but targeted areas with higher potential recharge, also applied across the eight rainfall zones.

Recharge estimates from the 2 scenarios in each rainfall zone were then applied to a 2-layer, transient MODFLOW (McDonald and Harbaugh 1988) distributed groundwater model. The upper layer of the groundwater model was attributed to represent the Parilla sand aquifer. Prior to the application of changed recharge conditions, the groundwater model was calibrated under historic current practice recharge estimates to match the time-varying groundwater bore hydrograph responses and mapped discharge sites within the catchment.

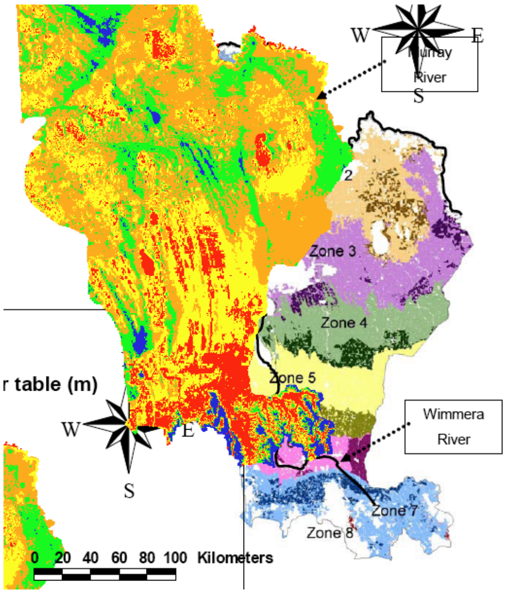

Figure 1 Extent of agricultural land in each rainfall zone and the location of both the Murray and Wimmera Rivers. Darker areas of shading indicate areas where lucerne was applied in Scenario 2 to target areas of highest recharge.

Results and discussion

To achieve a 20% recharge reduction target in this landscape would require lucerne adoption rates ranging from 21% (Zones 5 and 6) to 88% (Zone 1) using modelling inputs imposed using Scenario 1 (Table 1). Scenario 2 reduced the gross area of lucerne adoption needed in all rainfall zones to meet this RCT. The total adoption area needed was reduced by 65% from 1,169,625 ha to 407,743 ha with the greatest reduction achieved in the drier Mallee areas (Table 1). Even under the targeted approach of Scenario 2 the total area to treat with lucerne is large and further refinement in size of the target or the targeting priority areas needing protection within the catchment maybe necessary to achieve a more affordable option.

Treating the whole Mallee and Wimmera will at least reduce the saturated area by around 28,003 ha and saline flows into the River Murray by 118 ML/yr and Wimmera River by 63 ML/yr over a 20- year model-run period (Table 1). For the Mallee areas, the random approach in the dryland areas (Zones 1, 2 and 3) offers the greatest benefit, in reducing export of saline water to the River Murray. The remaining areas have little impact on the River Murray. In the Wimmera, however, the greatestimpact occurred through the 440-600 mm annual rainfall zone with a reduction in the area of saturated land of 9856 ha and reduced groundwater inflows to the Wimmera River of 38 Ml/yr, with little effect on the River Murray over a 20 year period. Primarily because of the distance of this Zone to Murray River and the transmissivity of the underlying groundwater aquifer, the impact within 20 years is minimal.

Table 1 Summary of mean annual current practice recharge and scenario analysis showing the area of lucerne needed under each scenario to reduce the recharge by 20% in each rainfall zone across the Mallee and Wimmera Parilla sand aquifer. The objective of scenario 2 was to target the areas of highest recharge that provide near equal volume of water controlled.

			Scenario 1 (recharge reduction across whole of Zone)					Scenario 2 (highest recharge targeted within Zone)				
Rainfall Zone (mm/yr)	Zone ID	Current Practice Recharge (mm/yr)	Lucerne area needed (%)	Lucerne area needed (ha)	Change depth to watertable <2m (ha)	Change groundwater export to Murray R (Ml/yr)	Change groundwater export to Wimmera R (Ml/yr)	Lucerne area needed (%)	Lucerne area needed (ha)	Change depth to watertable <2m (ha)	Change groundwater export to Murray R (Ml/yr)	Change groundwater export to Wimmera R (Ml/yr)
<290	Zone 1	1.1	88	276,963	94	37.39	0.00	22	68,778	81	10.51	0.00
290-320	Zone 2	1.4	46	348,245	100	56.20	0.12	10	78,493	112	6.01	0.00
320-340	Zone 3	2.5	32	185,813	218	24.21	0.06	7	42,833	50	0.01	0.00
340-350	Zone 4	6.4	25	113,881	4331	0.01	3.54	12	55,495	212	0.01	0.01
350-390	Zone 5	17.7	21	106,338	6715	0.01	2.54	13	63,779	212	0.01	0.07
390-440	Zone 6	33.5	21	52,258	6570	0.00	19.17	16	39,456	131	0.00	0.15
440-600	Zone 7	64.6	23	84,463	9856	0.00	37.57	16	57,570	887	0.00	1.81
>600	Zone 8	116.1	33	1,664	119	0.00	0.34	27	1,339	100	0.00	0.53
	Total	**14.6**	**36**	**1,169,625**	**28,003**	**117.82**	**63.34**	**13**	**407,743**	**1,785**	**16.55**	**2.57**

The results demonstrate that it is possible to achieve the RCT target of a 20% recharge reduction with a smaller area of lucerne adoption through targeting high recharge areas (Scenario 2). This improved targeting however, does not translate to a reduction watertable saturated area of the same magnitude. The results show that to achieve the RCT of a reduction in the area of salinised land then Scenario 1 would be more effective. This demonstrates that the use recharge reduction targets to represent a likely reduction of the area of land threaten by salinisation is flawed as similar recharge reductions can lead to different groundwater outcomes.

Conclusions

This study compliments a broader study of modelling the effects of landuse change with the objective of meeting Resource Condition targets for the Wimmera and Mallee regions. The objective has been to address important landuse change options being considered by the regional Catchment Management Authorities. The following outcomes are drawn from this modelling application:

- Using CAT the current practice mean annual recharge in the Mallee was 6.2 mm/yr whilst the Wimmera had a much higher rate of 38.4 mm/yr reflecting the wetter region.
- A targeted approach was shown to be more effective in reducing recharge. The total area was reduced by 65% from 1,169,625 ha to 407,743 ha with the greatest reduction achieved in the drier Mallee areas.
- For the Mallee areas, the targeted approach in the drier areas (<290 mm annual rainfall) offers the greatest benefit, followed closely by the 290-320 mm annual rainfall zone in reducing export of saline water to the Murray River. The remaining areas have little impact on export to the Murray River. In the Wimmera, however, the greatest impact occurred through the 440-600 mm annual rainfall zone.
- Within each Zone tested similar recharge reduction rates lead to different outcomes in groundwater and export to stream from the catchment area.
- The idea of a targeted approach to landuse change should be pursued further given the importance of major assets like the Murray and Wimmera Rivers.

Acknowledgments

The Catchment Analysis Tool (CAT) is a modelling framework developed with the funding support of the Victorian Government, CRC Salinity and Victorian NAP. This project application was made possible by the generous support and collaborative spirit of CSIRO Land and Water and the Victorian Department of Primary Industries in testing different models in a landscape context. The CRC Salinity, Land Technologies Alliance and the Victorian NAP office also strongly supported this study. The models used comprise many

assumptions. These assumptions provide a foundation for the development of the models, while there is a level of uncertainty associated with our models, the best available data has been used to limit associated errors.

References

Beverly, C., Bari, M., Christy, B., Hocking, M. and Smettem, K. (2005). Predicted salinity impacts from land use change: comparison between rapid assessment approaches and a detailed modeling framework. Aust. J. Exp. Agric. 45, 1453-1469.

Harbaugh A, McDonald M (1996) User's documentation for MODFLOW-96, an update to the U.S. Geological Survey modular finite difference groundwater flow model: U.S. Geological Survey Open-File Report 90-485, 56p.

Mallee Catchment Management Authority (2003). Mallee regional catchment strategy 2003-2008. ISBN 1-92077-00-8. www.malleecma.vic.gov.au/media/docs/RCS_2003-08.pdf

Wimmera Catchment Management Authority (2005). Wimmera regional salinity action plan strategy 2005-2010.
wcma.vic.gov.au/index.php?option=com_docman&task=doc_download&gid=42&Itemid=50

Weeks, A., Christy, B., Lowell, K. and Beverly, C. (2008). The Catchment Analysis Tool (CAT) – Demonstrating the benefits of interconnected biophysical models. *In* 'Landscape Analysis and Visualisation - Lecturer Notes in Geoinformation and Cartography'. Ed. Christopher Pettit, William Cartwright, Ian Bishop, Kim Lowell, David Pullar, David Duncan. Pub. Springer(Berlin) *in press.*