Reducing the Vulnerability of Societies to Water Related Risks at the Basin Scale
(Proceedings of the third International Symposium on Integrated Water Resources
Management, Bochum, Germany, September 2006). IAHS Publ. 317, 2007.

The relationship between native vegetation and in-stream salinity: an Australian case study

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Abstract The Glenelg-Hopkins area is a large regional watershed (2.6 million ha) in southwest Victoria that has been extensively cleared for agriculture. In-stream electrical conductivity (EC) in relation to remnant native vegetation is examined from the headwaters to the upper extent of the estuary of the Glenelg River. Five water quality gauging stations were selected. Their contributing subcatchments represent a continuum of disturbance. Proportions of native vegetation ranged from ~100% at the headwaters of the river to ~30% at the furthest downstream gauge station. The relationship between remnant vegetation and in-stream EC was examined using aggregated and non-aggregated land use statistics over a period of 22 years from three land use maps. Increased proportions of native vegetation were significantly negatively correlated with in-stream EC and were consistent across all scenarios investigated.

Key words dryland salinity, GIS, land cover, land degradation, land use, vegetation

INTRODUCTION

Natural salinisation of the Australian landscape throughout the geological record has been documented (Bowler, 1990); however, recent increases in salinisation are largely attributed to human activities. It is now widely accepted that large-scale land clearing to facilitate European style agriculture has promoted the spread of dryland salinity (Jolly *et al*., 2001). Removal of deep-rooted perennial vegetation and replacement with seasonal crops with a lesser capacity to utilize available rainfall has seen groundwater levels rise. Currently it is estimated that 2.5 million ha of land in Australia is affected by dryland salinity and it is forecast this may increase to around 15 million ha in the next 30–100 years (CSIRO, 2000). As much as 20 000 km of streams could be salt-affected by 2050 (National Land and Water Resources Audit, 2001).

The basic processes contributing to dryland salinity are well documented. But in some regions, a combination of the hydrological complexity of the Australian landscape, difficulties in implementing control treatments, and variable time lags associated with salinity and groundwater flows have all complicated research efforts

(Van Bueren & Price, 2004). These challenges exist in the most intensely studied areas on the continent; yet Australia also has other agriculturally significant regions from which markedly less data have been collected. It is in these data-poor regions where regional-scale salinity research is arguably in its infancy. The Glenelg Hopkins region in southwest Victoria is an example of this.

This paper will examine in-stream electrical conductivity (EC) in relation to the proportion of native vegetation cover from the headwaters to the upper extent of the estuary of the Glenelg River, the major river in the west of the region.

METHODS

Site description

The Glenelg Hopkins catchment is a regional watershed in southwest Victoria, Australia, covering approximately 2.6 million ha. Less than 20% of the original vegetation remains in the region (GHCMA, 2002). Groundwater flow patterns have been altered following clearing of deep-rooted native vegetation and groundwater extractions (National Land and Water Resources Audit, 2001). It is estimated that 144 500 ha of land is affected by dryland salinisation (National Land and Water Resources Audit, 2001). The Glenelg Hopkins region is considered to be one of the areas most at risk from rising water tables and dryland salinity in the next decade (GHCMA, 2002).

GIS and statistical methods

Surface water data and latitude and longitude coordinates were obtained from the Victorian Water Quality Database. Catchments were delineated following Versace *et al.* (2005). The mean proportions of native vegetation were calculated from land use maps for the years 1980, 1995, and 2002 (Ierodiaconou *et al.*, 2005). The mean electrical conductivity was calculated for all available years and years for which data corresponded to land use maps for comparative purposes. Simple linear regression analyses were performed at two spatial scales. Aggregated analyses used the proportion of native vegetation from the entire area upstream of the gauging station. This approach accounts for all upstream land use contributing to water quality at a given gauging station. Non-aggregated analyses only accounted for the proportion of native vegetation in the subcatchment immediately upstream of the gauge station, and did not account for land use beyond the immediate upstream gauge station. Electrical conductivity data were $\log_{10}$-transformed prior to regression analyses. Testing the null hypothesis of no difference in slope between aggregated and non-aggregated analysis was done using the Test for Parallelism (Kleinbaum & Kupper, 1978).

RESULTS

Aggregated proportions of native vegetation show a continuum of disturbance from the head waters (Subcatchment 238231) to the upper extent of the estuary (Subcatchment

Table 1 Aggregated and non-aggregated land cover statistics by site.

Site code	Catchment area (ha)	Proportion of native vegetation 1980[N]	 1980[A]	 1995[N]	 1995[A]	 2002[N]	 2002[A]
238231	5921	0.999	0.999*	0.999	0.999*	0.999	0.999*
238236	129884	0.773	0.783	0.775	0.784	0.777	0.787
238205	1010	0.605	0.782	0.605	0.783	0.605	0.785
238202	282807	0.288	0.432	0.280	0.428	0.279	0.428
238206	199027	0.375	0.315	0.317	0.301	0.303	0.298

[N] Non-aggregated land cover statistics

[A] Aggregated land cover statistics

*Non-aggregated and aggregated statistics identical

Table 2 EC total data availability and data availability corresponding with land use maps.

Location (Site code)	Year (*n*)	Mean EC available all years (SE)	Mean EC years with land cover information (SE)
238231	1980–2002 (274)	118 (3)	136 (21)
238236	1992–1997 (107)	507 (7)	480 (10)
238205	1991–2002 (146)	694 (24)	660 (49)
238202	1980–2002 (276)	3663 (99)	3722 (249)
238206	1980–2002 (282)	2644 (66)	2654 (114)

n Number of EC observations available between 1980–2002

SE Standard Error

Table 3 Summary of regression analyses.

Year	Aggregated	Land use	β	*T*–value	Coefficient *P*–value	R^2
All	No	Constant	4.067	122.375	<0.001	0.911
		Native Vegetation	–1.982	–38.098	<0.001	
All	Yes	Constant	4.208	86.297	<0.001	0.850
		Native Vegetation	–2.015	–28.409	<0.001	
1980	No	Constant	4.096	83.737	<0.001	0.953
		Native Vegetation	–2.022	–26.374	<0.001	
1980	Yes	Constant	4.193	55.320	<0.001	0.905
		Native Vegetation	–2.090	–18.038	<0.001	
1995	No	Constant	3.992	60.052	<0.001	0.859
		Native Vegetation	–1.905	–18.765	<0.001	
1995	Yes	Constant	4.172	49.834	<0.001	0.830
		Native Vegetation	–1994	–16.839	<0.001	
2002	No	Constant	4.113	84.197	<0.001	0.934
		Native Vegetation	–2.009	–25.468	<0.001	
2002	Yes	Constant	4.263	48.773	<0.001	0.838
		Native Vegetation	–1.988	–15.624	<0.001	

238206), a pattern that is evident at all three time periods (Table 1). The non-aggregated statistics do not concur with this. Subcatchment 238206 has more native vegetation than subcatchment 238202 immediately upstream (Table I). Data availability, the mean EC from all available years, and the mean EC used in the regression analyses are presented in Table 2. Regression analyses showed significant relationships for all combinations of aggregated and non-aggregated land cover statistics examined (Table 3).

DISCUSSION

The results of this study support the concept of elevated salinity following clearance of native vegetation. This widely promoted mechanism has been linked to the region (National Land and Water Resources Audit, 2001); yet other authors remain less convinced of this single mechanism being solely responsible (Nathan, 1999; Dahlhaus, 2002). Dahlhaus *et al.* (2002) makes the observation that primary salinisation of land and water assets in the region were more prevalent prior to landscape-scale changes than first thought. Logically this implies the geomorphology of the region cannot be ruled out as a substantial contributor to in-stream salinity. Ultimately in-stream salinity is likely a function of historical and prevailing land use, climate, groundwater levels and salt concentration, or complex interactions between these factors. Given the focus on maintaining and restoring deep-rooted perennial vegetation by salinity researchers, and considering the results here, native vegetation may provide an appropriate surrogate measure of these at the catchment scale.

The downstream pattern of vegetation cover observed is loosely consistent with many examples where high relief areas unsuitable for agriculture are left largely unaffected whereas flatter, lowland areas are farmed extensively. Therefore, it may be argued that that the downstream increase of salt may be a cumulative effect. However, the non-aggregated native vegetation statistics indicate greater cover in subcatchment 238206 in comparison to 238202, which also corresponds with significantly lower in-stream salinity. This may be explained by higher rainfall in the south of the region combined with the Lower Glenelg National Park, which comprises a substantial proportion of this subcatchment 238206. This example serves to identify the importance of getting more information to model dryland salinisation at the catchment scale.

In conclusion, a significant relationship between reduced native vegetation and elevated salinity has been shown. As many modern management methods are adaptive and based upon the best available information, a finding of this type should not be ignored. Whilst it would be premature to implement management based upon these findings, they do suggest native vegetation in the region may provide a surrogate measure of other processes, both natural and human-induced. This study has demonstrated the potential of combining existing data sources integrated in a GIS environment to understand regional scale dryland salinisation.

Acknowledgements The first author would like to acknowledge the support of Land and Water Australia (Land and Water Australia Travelling Fellowship, DUV7), the Victorian Department of Primary Industries (Nancy Millis Postgraduate Award), and the Glenelg Hopkins Catchment Management Authority.

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