Long-term groundwater trends and their impact on the future extent of dryland salinity in Western Australia in a variable climate.

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Introduction

Consecutive West Australian Governments have fostered agricultural development in the 'Wheatbelt'. Excluding the forested Darling Ranges, this part of south-western Australia covers about 24 M ha. Native, perennial, deep-rooted forests and woodlands were cleared in phases. Land releases increased after each World War. For example, in the 15 years after World War 2, the cultivated area increased from 5.6 M ha to 10 M ha. Similarly land releases in the 1960s alienated an additional 3.5 M ha. By 2001, when clearing had effectively ceased, over 19 M ha of land had been converted to annual crops and pastures. Residual forests (>4 M ha) only remain in the Darling Ranges, parts of the Perth Basin and as isolated remnants in the wheatbelt.

Changes to the environment followed the plough. While W.E. Wood (1924) first published the details of a causal link between clearing and salinity, it was not until the 1950s that dryland salinity emerged as a major farmland and water supply issue. By this time, a survey of farmers revealed that 40,000 ha of previously arable land had become salt affected, and over 400,000 ha was at risk (George 1990).

The extent of salinity has been tracked using a combination of methods, at a range of scales. Extensive surveys of salinity were undertaken by the Australian Bureau of Statistics and Department of Agriculture, every 5 years over a 47 year period. While the questions asked have varied slightly, farmers surveyed report the area saline has increased from 73,476 ha (1955) to 932,695 ha (2003).

Between 1996 and 2000, the Land Monitor project used satellites and a high resolution Digital Elevation Model (+/- 1m) to estimate salinity at paddock-scales. Interpretation noted that 992,000 ha of the wheatbelt, including 821,000 ha of agricultural land, were severely salt-affected. An additional area of land was also classified saline (85,700 ha) within palaeodrainages (336,580 ha). The Project also estimated the equilibrium valley hazard (not risk) using a Digital Elevation Model and rule based approach. This area was forecast to be between 2.8 and 4.4 M ha.

Prior to the publication of the Land Monitor, the NLWRA (2000) reported a salinity assessment conducted across all Australian States. In Western Australia, Short and McConnell (2001) reported that 3.552 M ha were classed as prone to salinity at 2000 (16%; defined as the watertable between 2- 5m below ground surface with rising trends), 4.181 M ha (21%) would be at risk by 2020 and 6.490 M ha (33%) at equilibrium (>2100).

Watertable Analysis

Rotary-Air-Blast drilling rigs, operated by regional hydrologists of the Department of Agriculture and Food were used to establish a network of 1318 long-term monitoring bores [termed SALTWATCH bores]. These bores exist in clusters at about 100 catchments/sites across the agricultural regions, representing most of the 19 M ha cleared area. Bores were typically drilled to basement, on transects from upper to lower slopes, or in areas that were saline or were suspected of having a significant risk.

Manual time series analyses of trends in all bores were undertaken (<1990, 1990-2000, 2000-, and all periods) and presented for two time periods (Table 1). Analysis of each period was conducted by calculating the dominant trend. Linear trends were simple to assess, however if there was significant seasonal variability, trends were derived from a line of best fit connecting summer minima. These results are contrasted to rainfall data for five stations, one from each region, where Accumulated Monthly Residual Rainfall (AMRR 1975-1999) is compared pre and post 2000.

Table 1. Bores analysed for groundwater trends 1990-2000 (n=990) & post 2000 (n= 1318 bores)

Region	Bores #	Pre 2000			Post 2000		
		Rising	Falling	Stable	Rising	Falling	Stable
Northern	109-170	66%	6%	27%	18%	69%	13%
Central	299-479	47%	5%	47%	23%	37%	40%
South-West	331-370	53%	3%	44%	37%	12%	52%
South Coast (West)	76-80	74%	17%	9%	50%	31%	17%
South Coast (East)	175-219	72%	5%	23%	71%	7%	22%

Bores qualified for inclusion in the analyses if they were located in cleared agricultural land, remote from the effects of any salinity management treatment (drains, trees, perennial pastures) and met minimum standards (e.g. 5 years duration and/or 20 monitoring observations). The average catchment had 14 bores and 50 groundwater observations. Trend analyses were conducted on between 266 and 1318 bores [<1990 (n=266), 1990-2000 (n=990), 2000-07 (n=1198), and ALL (n=1318)].

Bores were not sorted by soil-landscape zone. For example, in some catchments the proportion of bores in valleys with shallow watertables dominated (eg Central Region where Wallatin and Beacon catchments had 72-83 bores in areas where average watertables were < 3m), while other catchments were dominated by bores with deep watertables (e.g. NE Yilgarn = 9 m and East Belka = 12m).

Results

The relative proportions of groundwater bores with rising trends changed after 2000, both in terms of the amount and degree of rise/fall, and also spatially across the five regions. Prior to 2000, in four regions, between 53-74% of all bores had rising trends and <6% had a falling trend. About 9-47% had no trend (stable). Pre 2000, the western South Coast had the greatest number of falling trends (17%) and also had fewest stable trends (9%). After 2000, the number of bores with rising trends decreased in 4 out of the 5 regions. This was most pronounced in the Northern region (18%), and progressively reduced towards the eastern South Coast where the number pre & post 2000 was unchanged (71-72%).

Groundwater trends differ depending on the depth to watertable. Plots of trend by depth for each time period (<1990, 1990-2000, All time) for the five regions (Figure 1) show that prior to 2000, nearly all bores displayed a rising trend whether the watertable was shallow or deep. However, after 2000 (b plots) trend appeared dependant on depth to watertable. In the Northern region, downward trends, to - 0.5 m/yr, were most common in bores with shallow watertables (<10m), less significant falls (-0.2 m/yr) were apparent for deeper watertables, to >30m. In the Central region, falls were less (-0.2 m/yr) and all but three were observed where watertables were <10m. In the South West and Western South Coast falls were less (<-0.1 m/yr), and were observed at <5m watertable depths. By contrast, in the Eastern South Coast, the trends pre and post 2000 remained the same; upwards (>0.2 m/yr) or stable.

In addition to a reduction in the number of post 2000 bores with rising trends, the magnitude of rise diminished from north to south (Figure 2c). In some Northern region bores, rises in the 1990s were offset by falls post 2000. However, this wasn't the case in the entire Northern region (eg not Perth Basin), nor in most other regions, where watertables rose (<1990-2007). In the Central, South West and Western South Coast regions, it was usually only 'discharge' bores that demonstrated falling trends (<-0.2m/yr >2000). Bores in areas of valley hazard and uplands, or those remote from discharge zones, continued to rise.

After 1975, South West annual rainfalls reduced. However, since 2000 in the North and West (Morowa, Narrogin), rainfall has been further reduced (Figure 1). By contrast, it has increased in the south-east (Esperance) and slightly in the Central (Merredin) region, the later due to three large events.

Discussion

We attribute the observed groundwater responses to the interaction between three factors; clearing, reduced rainfall, and the onset of hydrologic equilibrium. Experimental data implicates clearing as the dominant causal factor in groundwater rise and the expansion of land salinity (Peck and Williamson, 1989). The analyses presented here allow some insight into the impact of the other two factors.

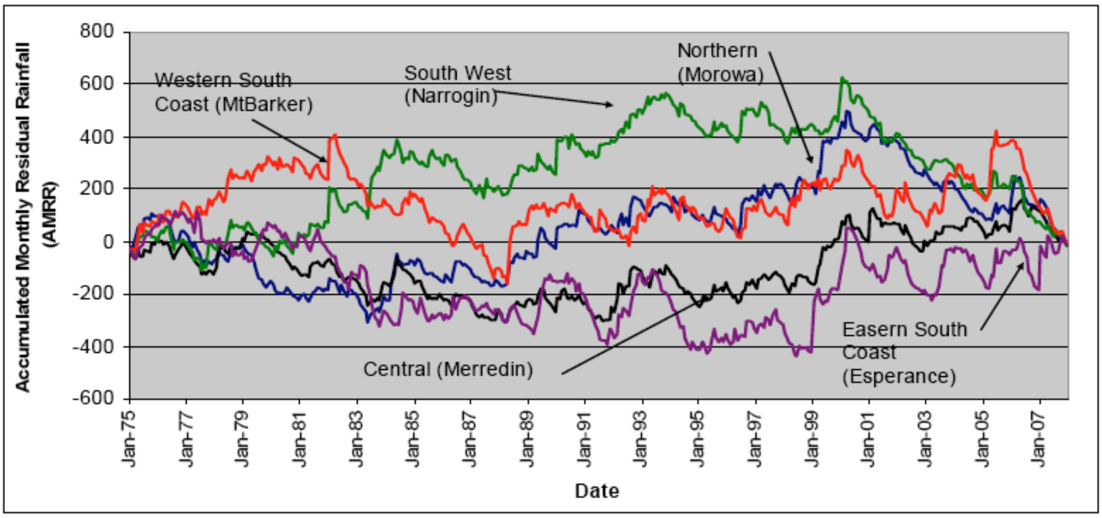

Figure 1. AMRR plots for five stations within the agricultural areas investigated.

Rates of groundwater rise observed from 1975 to 2000 were significant and occurred over a period where the area of saline land grew from 167,000 to 1 M ha. We attribute this rise primarily to landuse change brought about by the scale of clearing which preceded it. Notably, this 25-year period was one of reduced rainfall relative to the previous 50 years in all areas except the eastern South Coast.

Since 2000, the numbers of bores with rising trends and their rates of rise have decreased. However, this response varies spatially, with most reductions in the Northern region, and none in the eastern South Coast. Persistent drought and high evaporative demand in the Northern region (>20% rainfall reduction) appears to have negated previous watertable rise. By contrast, in much of the Central, SW and western South Coast, changed rainfall has not caused the same degree of reduction. Notably, in the South West, the post 2000 reduction (Narrogin, Figure 1) has not caused obvious change, while on eastern South Coast (Esperance), where rainfall has increased, trends remain upward.

Rates of groundwater rise are affected by the degree to which the catchment has responded to clearing. In catchments still actively filling [not near equilibrium], reduced rainfall-recharge appears to have had no discernible impact on rising trends. Later, as these catchments approach equilibrium, and discharge areas grow, climate impacts will become the dominant controller of trends. Finally, as noted, the dataset has not been analysed by landscape position, thus we have some over-represented some landscapes and some with little or no data. A drilling program underway will in-fill the gaps.

Despite lower than average rainfall over much of the wheatbelt since 2000, we continue to see salinisation expand in all regions, especially following episodic floods, such as occurred in 1999-2000, 2001 and 2006. Hence our measured reductions of watertables in some wheatbelt valleys may be as much attributed to recessions between these floods, as to a shift in mean annual rainfall.

The recent change in groundwater trends may have a significant implication for assessing the likely future extent of salinity and the effect of management, especially those established as a result of the National Action Plan for Salinity and Water Quality. Observed reductions in watertable must be corrected for climate. Failure to do this may exaggerate the expected benefits of management.

References

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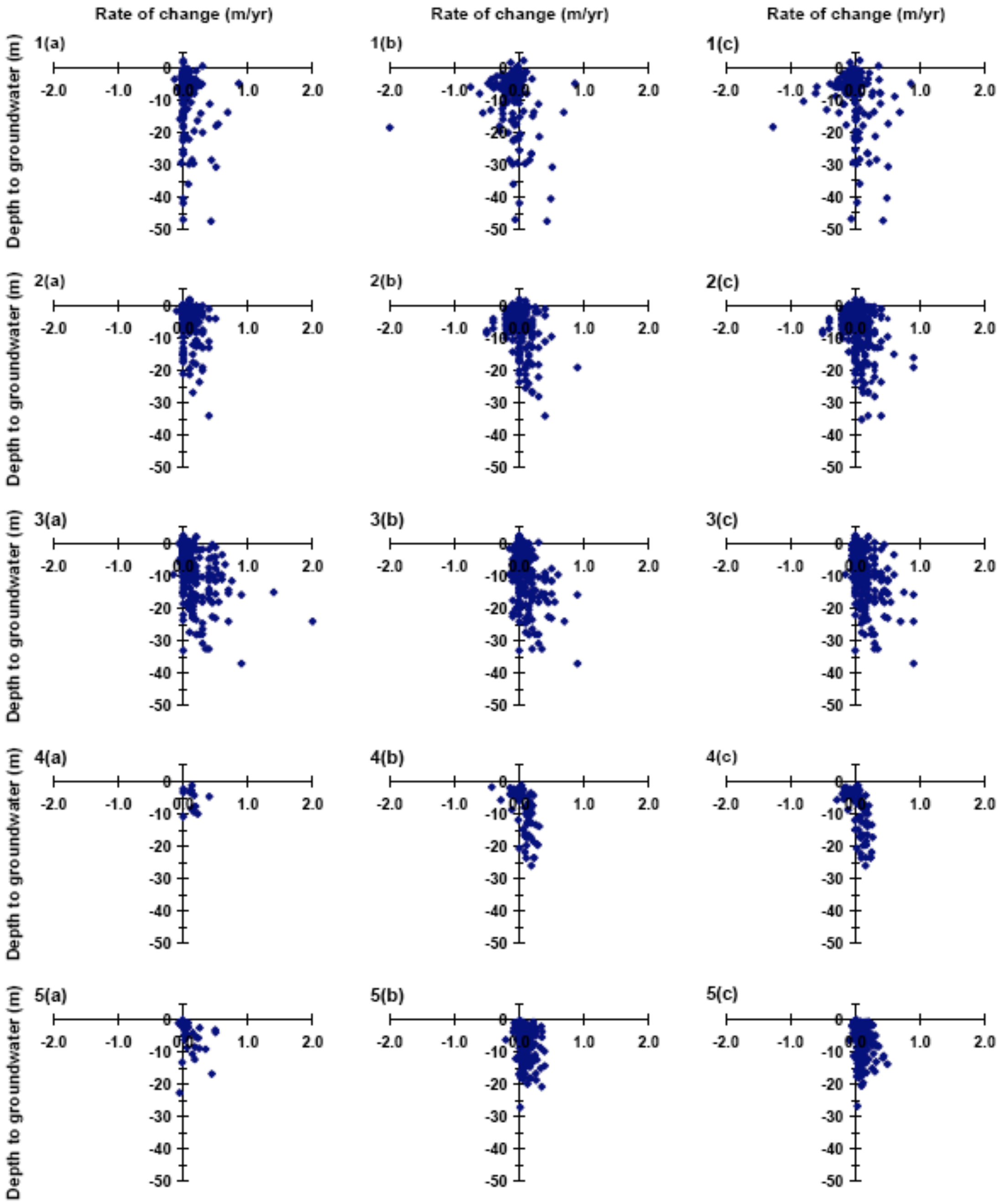

Figure 2. Hydrograph derived trend analysis (+ Rise / - Fall) by Depth to Groundwater (2005-2007), for all bores in Agricultural Regions (1=Northern, 2=Central, 3=South West, 4=South Coast-West and 5=South Coast-East) for periods (a) <2000, (b) 2000-2007 and (c) All record (>1975-2007).