DRYLAND SALINITY IN SOUTH EAST AUSTRALIA: A LOCALISED SURFACE WATER AND SOIL DEGRADATION PROCESSES?

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INTRODUCTION

Salinity is a high priority issue in Australia. The currently promoted general cause of secondary dryland salinity in southern Australia, the *Rising Groundwater Model* (RGM), is controversial (HRSCSI 2004, Passioura 2005; Wagner 2005, Tunstall 2005, Keogh 2005; Bann & Field 2006a,b; Coulthart 2006). This simple model is promoted on national internet websites (e.g. Australian Academy of Science, Australian Conservation Foundation, CSIRO, CRC Dryland Salinity, National Dryland Salinity Program, NSW Department of Natural Resources, and the Bureau of Rural Sciences) and is embedded in practically all Australian scientific articles related to dryland salinity. However, the model has not been proven to be that general thus far. To the contrary, the RGM has been questioned by many researchers, particularly in southeastern (SE) Australia (e.g. Jones 2000; Dehlhaus et al. 2000; Acworth and Jankowski 2001; Paulin 2002; Rengasamy 2002, 2006; Fitzpatrick et al. 2003; Tunstall 2004, 2005; Fawcett 2004; Wagner 2001, 2005; Edwards & Webb 2006; Bann & Field 2005, 2006a,b). Rengasamy (2002, 2006) and Fitzpatrick et al. (2003) have indicated that another form of salinity, termed *'transient salinity'*, is the predominant salinity process in SE Australia. However, this model of salinity has been ignored in the majority of research and extension activities focused on dryland salinity. This has had, and still has, major consequences for dryland salinity natural resource management activities carried out in SE Australia. This paper explores the RGM in SE Australia and discusses the alternative model, the transient salinity or *Surface Water Model* (SWM), as proposed by Bann and Field (2006a). We suggest future directions for dryland salinity management activities carried out in southern Australia.

The Rising Groundwater Model

The RGM is the officially promoted secondary dryland salinity model in SE Australia. This simple model invokes an excess of water moving through the landscape, caused from the extensive removal of perennial vegetation (trees) from the hills; subsequently generating significant increases in 'recharge' to deep groundwater, which then 'rises', or 'discharges' somewhere downslope. During the journey it travels through ancient 'bulges', or deposits of salt, which it transports to the surface. These salt deposits were apparently lying 'dormant' prior to this relatively recent mobilisation. However, Bann and Field (2006a) list numerous assumptions made by the RGM and highlight many situations where it is inapplicable and certainly not general (see Table 1). We are not suggesting that the RGM is not a probable cause for many dryland salinity outbreaks, especially in Western Australia. However, we indicate that evidence suggests that it is not the dominant salinity model explaining salinity outbreaks on the uplands of SE Australia. This is of paramount importance, particularly for sustainable natural resource management activities.

The Surface Water Model

Another form of dryland salinity, termed transient salinity (Rengasamy 2002, 2006; Fitzpatrick et al 2003), involves soil surface processes and is suggested to be the dominant cause of dryland salinity in upland landscapes of SE Australia, affecting up to 67% of agricultural land. Bann and Field (2006a) suggest a more suitable term for transient salinity is *surface water salinity*. This accounts for the salinity that is not 'transient', but still occurs due to soil processes and can be called the Surface Water Model (SWM). The effects of grazing on soil degradation are well known, especially for fragile, duplex soils of SE Australia (e.g. Greenwood et al. 2001; Yates et al. 2000). Greenwood et al. (2001) indicate that soil degradation due to stock grazing is particularly prevalent in wet soils (i.e. discharge zones) and Bann & Field (2006b) suggest that soil degradation processes subsequent to intensive grazing are the dominant cause of salinised sites on the Southern Tablelands of NSW (STNSW).

Table 1. Assumptions made for the dryland salinity 'rising groundwater model' (RGM) (adapted from Bann & Field 2006a).

* The one model applies to all situations
* Landscapes were 'balanced' or in 'equilibrium' prior to European settlement
* Most rainfall was evapotranspired or ran through chains of ponds prior to European settlement
* Significant fluctuations in rainfall have had little influence
* All landscapes were extensively cleared of deep rooted vegetation, especially trees
* Geology is simple and uniform and does not influence processes
* Groundwater and surface water readily mix
* Landuse activities influence groundwater
* Trees have the ability to 'contain' large amounts of salt in the soil root zone.
* Salt stores ('deep bulges') have been lying 'dormant' for millennia
* Discharge is 'rising groundwater'
* There is an excess of water movement in the landscape (despite the recent drought & storage effects of dams)
* Secondary salinity is not primary salinity (or derived from)
* Soil surface processes are not involved
* Recharge (percolation) only occurs on the hills and is homogeneous across them
* Natural drainage on lower slopes (and/or discharge zones) is not considered

SITES AND METHODS

Numerous sites exhibiting increased salinity levels were inspected in Tasmania, Victoria, the Hunter Valley and the STNSW. Ten sites on the STNSW between Canberra and Boorowa were subsequently chosen for intensive research into dryland salinity geophysical and biophysical processes. All sites chosen:

1) were within the Murray Darling Basin (Lachlan and Murrumbidgee River Catchments);
2) exhibited increased salinity levels (scalds, EC, EM38/EM31 surveys, 'indicator' species, dead/dying trees);
3) contained yellow box (*Eucalyptus melliodora*) and red gum (*E. blakelyi*) grassy woodland;
4) were relatively less disturbed from previous and present anthropogenic activities and;
5) were located on Travelling Stock Reserves, a Nature Park and Crown Land within 2 hours drive of Canberra.
6) were located on Ordovician and/or Silurian quartzo-felspathic metasediments and volcanics of the Lachlan Fold Belt.

A suite of biotic and abiotic measurements were made at all ten sites to determine the fundamental processes within the system. These included;

- field surveys such as soil and water EC, EM38 and EM31, soil infiltration
- laboratory analyses such as soil pH, EC, cations and anions
- hydrology surveys and analyses such as piezometer monitoring,
- various flora and fauna surveys and
- the Landscape Function Analysis technique (Tongway and Hindley 2004).

Various landuse, landscape and geology parameters were also described. Measurements were taken from 2004-2006.

OBSERVATIONS AND RESULTS

Salinised sites in SE Australia are generally small (sometimes only a few metres in diameter), localised and associated with intensive stock grazing and soil degradation. Many sites have not been cleared of their original vegetation, particularly on the hills (Fig 1). Determining whether a site is primary and/or secondary salinity is problematic, as salinity is a primary long term feature in the landscape (van Dijk 1969; Bann & Field 2005, 2006a), and historical records of the area are generally anecdotal (Wagner 2001). Runoff across the landscape is considerable and areas of low elevation are generally eroded with exposed, surface crusting, dispersible, sodic A2 and B horizons (Fig 1), which are endemic to the landscape (van Dyjk 1969; Gunn 1985; Acworth & Jankowski 2001). Infiltration is highly variable across the landscape but appears to be generally highest beneath tress in woodlands where a relatively non-compacted A0/A1 horizon exists. Infiltration is very low on the scalds. This concurs with the results of Eldridge and Freudenberger (2005) that indicate that infiltration (and recharge) is higher beneath trees than in adjacent grazed grassland, and Greenwood and McKenzie (2001) who indicate that infiltration is reduced following intensive grazing (i.e. recharge decreases following tree removal and grazing). Piezometer monitoring indicated lateral surface water movement above semi-impermeable clay-rich B horizons (i.e. perched soil water tables and interflow).

This water flow is present immediately following rainfall, as previously indicated by Gunn (1985) and Kreeb et al. (1995). No evidence was found on any of the ten research sites for regional rising groundwater or for expansion in size during the 3 years of monitoring. This agrees with Wagner (2001, 2005) who based his conclusions on the investigation of 90 sites in SE NSW, but contradicts suggestions that salinity is expanding at an alarming annual rate (e.g. compare: PMSIEC 1999; MDBMC 1999; NLWRA 2001). Soil salinity is generally low (ECw <2 dS/m) and highly variable both spatially (vertically and horizontally) and temporally, with the majority of salt occurring at the soil surface, particularly during the hotter months following rainfall (i.e. increased evaporation rates). Salinised scalds contain both acidic (soil pH_w ~4) and highly alkaline soils (soil pH_w ~11), as indicated by Kreeb et al. (1995) who investigated scalds on the Northern Tablelands of NSW. The chemistry factor may be influenced by the geology. Further cation and anion analyses are presently being undertaken. Boundaries between vegetation and scalds are abrupt, indicating a sudden change in conditions, such as that produced by soil degradation rather than a regional problem. Moreover, many expressions are caused by roads across drainage lines, (inhibits/concentrates surface water flow), below roads (causing increased runoff onto the site) and in the case of unsealed roads (tracks), upon the road surface itself (soil degradation). All of these occurrences are produced by increased surface water evaporation and soil degradation processes, and are unlikely to be due to deep groundwater processes. Observations and results from this research indicate that secondary salinised sites on the STNSW are likely to be caused by surface water and soil degradation processes (see Table 2). The majority of parameters measured and observed on the uplands of the STNSW support the SWM.

Table 2. Results summary showing the relationship between the Rising Groundwater Model and the Surface Water Model at most secondary dryland salinity sites on the STNSW. Yes = supports the model; No = does not support the model. Many parameters have question marks due to the uncertainty as to the causes and/or, were not actually observed.

Parameter	Rising Groundwater Model	Surface Water Model
Rising groundwater proven to exist	No?	No?
Woody vegetation cleared from hills	No	No
Sites generally localised (<1-2 Ha)	No?	Yes
Accounts for small scalds	No	Yes
Sites associated with stock grazing	Yes?	Yes
Sites eroding with exposed sodic soils	Yes?	Yes
Significant runoff following rainfall	Yes?	Yes
Perched water tables following rainfall	Yes?	Yes
Assumed recharge and discharge zones	Yes	Yes
Salt tolerant flora survival	Yes?	Yes
Accounts for the affects of roads and tracks	No	Yes

Figure 1. The most publicised example of dryland salinity in NSW occurs at Dicks Creek, just outside the ACT. The site has long been used to illustrate the applicability of the rising groundwater model and consequent land management problems. Highly eroded and exposed A2 and B horizon duplex soils are evident with water draining down the hillslope over and through the soil (interflow). Incised drainage rills and gullies drain water from the soil profile and flow is primarily lateral. The electrical conductivity (EC) and EM 38 & 31 indicate low levels of salinity. This site is intensively grazed by livestock which have disturbed the soil surface, and trampoling and water and wind erosion have caused the land degradation. Note also the substantial woody vegetation on the surrounding hills.

DISCUSSION

Despite being a high priority environmental issue for a number of years, salinity mitigation efforts based on the RGM appear to be failing (Williams et al. 2001; Barrett-Lennard et al. 2005). In addition, observations and studies have indicated that in many situations, the process is inapplicable. Independent farmers and land managers are successfully mitigating and remediating salinity outbreaks by ameliorating the soil ('health') and applying the SWM (e.g. Nicholson & Seis 1993, Paulin 2002, Malcolm 2005; Barrett-Lennard et al. 2005; Coulthart 2006). Further collaboration and research needs to promote these success stories, rather than the present criticism.

Comparisons with Western Australian sites have not been made, as the authors have not carried out comparable research there, however, many sites in SE Australia do appear to support similar principles.

We suggest that the current salinity natural resource management activities in upland landscapes of SE Australia that are solely based on the RGM need to be researched. It appears that the predominant salinity processes are occurring within the soil and at a localised scale. Planting trees across 'recharge zones' is expensive, impracticable and in the majority of cases, has not achieved the desired outcomes (Wagner 2001; Williams et al. 2001; Barrett-Lennard et al. 2005). A greater emphasis is required to research the processes associated with the SWM. We suggest further mitigation and remediation activities in upland landscapes needs to include the SWM (and soil degradation processes), at both local and regional scales. The SWM advocates the amelioration and prevention of soil degradation by excluding set stocked grazing, with appropriate erosion control works and local revegetation. This includes focusing on the so-called discharge zones (e.g. scalds) and includes the planting of (native) trees and groundcover (e.g. grasses) within, immediately upslope, and in surrounding areas around increased salinity, including scalds, combined with appropriate soil works and grazing management (i.e. seasonal and / or 'crash' grazing). As increased salinity levels and other unfavourable growing conditions (e.g. temperature extremes, exposure, erosion, and soil compaction) at salinised sites are generally highest at the soil surface, we suggest that the use of endemic long-stem tubestock (Hicks et al. 1999) be investigated for management of such sites. This technique allows the plant roots to be planted up to 100cm below the surface and initial trials at saline sites have had positive results (Hicks 2003).

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