DRYLAND SALINITY, REGOLITH AND BIODIVERSITY: PROBLEMS AND OPPORTUNITIES FOR MITIGATION AND REMEDIATION

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INTRODUCTION

Human-induced ecosystem stresses are causing the demise of Australia's biodiversity. Dryland (secondary) salinity is considered to be a major human-induced land degradation problem in southern Australia (NLWRA 2000) and yet surprisingly little research has investigated the effects of increased salinisation on terrestrial biodiversity, especially in south eastern Australia.

The Yellow Box (*Eucalyptus melliodora*) and Blakely's Red Gum (*E. blakelyi*) Grassy Woodlands (YBRGGW) are listed as Endangered Ecological Communities in the ACT and NSW, having been cleared for agriculture since European settlement. YBRGGW occupy some of the more fertile soils on the lower inland slopes, extending along a belt from Victoria to south-east Queensland. It is in these low relief areas that dryland salinity also occurs, adding an additional stress to the woodland biodiversity. Interactions between the regolith, dryland salinity and terrestrial biodiversity are complex; identification of the fundamental processes acting upon the system essential for mitigation and remediation activities.

This research aims to quantify the effects of dryland salinity (increased salinisation) on ecosystem function and terrestrial biodiversity in the YBRGGW of south-eastern NSW. As the problem is multifaceted, an holistic, multidisciplinary approach is essential, using biotic and abiotic measurements. These include EM31 and EM38 ground-based electromagnetic surveys, field and laboratory soil and leaf analyses, invertebrate surveys and the use of the 'Landscape Function Analysis' (Tongway & Hindley 2004) and 'Habitat Hectares' (Parkes *et al.* 2003) ecosystem survey techniques.

Confounding variables such as dieback, drought, heavy grazing and other past landuse practices, combined with a lack of suitable research sites have created difficulties in project design and implementation. In addition, the current accepted theory on the cause of dryland salinity may not be applicable to many upland environments, especially within the Southern Tablelands of NSW (STNSW). This has major implications for mitigation and remediation activities and funding priorities.

This paper summarises problems experienced when undertaking this type of field-based research. We suggest ways to overcome these problems, and consider opportunities for mitigation and remediation activities.

SOURCE AND HISTORY

Salinity is a natural phenomenon in the Australian landscape (Crowley 1994) and sodic soils are common in southern Australia, especially in the lower parts of the landscape (Naidu *et al.* 1995). The main source of this salt is difficult to determine however, meteoric deposition from rain and dust (cyclic salt), connate salt from Palaeozoic marine sediment deposition, and regolith weathering must all be significant when considered over long periods. Some of the world's largest evaporite deposits are found in ancient Australian basins (Wells 1980). Many playa lakes exist today, and primary salinity is a feature of southern Australia (Crowley 1994). Dryland salinity (secondary salinity) usually forms where annual rainfall is between 400 and 800 mm and where evapotranspiration exceeds precipitation (NLWRA 2000). Distinguishing primary salinity from secondary salinity is problematic (Bann & Field in press) and salinity levels prior to European settlement are unknown; high salinity in some areas may well be completely natural.

DRYLAND AND TRANSIENT SALINITY

The cause of dryland salinity in south-eastern Australia is contentious. The current model used to explain the cause of dryland salinity, with designated recharge and discharge zones and rising watertables due to perennial vegetation clearing (Spies & Woodgate 2004), does not comply in many situations (Jones 2000, Bradd 2003, Rengasamy 2003, Tunstall 2004, HRSCSI 2004, Bann & Field in press). It appears that many dryland salinity outbreaks have no relationship with 'rising' groundwater. South-eastern Australia has been experiencing a significant drought, yet an excess of water is blamed for increased salinity. Historic rainfall data (BOM 2005) and research into more pluvial regimes (e.g., Crowley 1994, Page & Nanson 1996, Nanson *et al.* 2003) indicates south-east Australia has experienced much wetter periods during the Quaternary and

In: Roach I.C. ed. 2005. *Regolith 2005 - Ten Years of CRC LEME.* CRC LEME, pp. 8-12.

indeed the Holocene. This rainfall must have been excess to that which the vegetation could evapotranspire, particularly during the colder months, even prior to the extensive land clearing practices undertaken since European settlement. In addition, removing trees from recharge zones actually decreases infiltration rates and recharge (Eldridge & Freudenberger 2005). The argument for a recent increase in recharge and groundwater is thus invalid. The rising groundwater model also ignores complex, fundamental processes acting within and upon the regolith (see Table 1). Rengasamy (2002) explains how accessions from surface lateral movement of water causes increased salinisation, which is a soil-related process and nothing to do with the groundwater. He calls this ‘transient salinity’, however, we suggest this is an inappropriate term as it inplies the salinity is quickly passing through. This may be the case in some situations but many areas suffering from water pathway restrictions are not transient. Transient salinity fluctuates with depth and changes in concentration, and its affect on plant growth varies over seasons and with rainfall (Rengasamy 2002).

Table 1: Summary of the main influences and considerations when researching dryland salinity.

* Secondary (human induced) or primary (natural)?
* Climate and distance from coast
* Geology (lithology, faults, joints, cleavage, dip, dykes, contacts and lithology changes, groundwater flow systems, permeability, porosity) - heterogeneous
* Salt source and movement - palaeodrainage, flow pathways, blockage and accession, perched water tables, infiltration and leaching, salinity depth, aquifer depth, watertable depth, recharge/discharge
* Soils/regolith (chemical, physical, biological properties) - heterogeneous
* Size, severity, stage (onset/climax/recovery) of site
* Significant spatial variation over small distances
* Temporal variability (seasons, annual, long term)
* Topographic setting (e.g. surface and subsurface flows and runoff)
* Salt type and concentration
* Vegetation cover
* Anthropogenic disturbances (past and present)
* Grazing (especially sheep, horses and goats)
* Vegetation clearing – soil degradation, erosion
* Cropping, plantings and fencing
* Soil works (contour banks, fallowing, tillage, dams)
* Roads and tracks (drainage and compaction)
* Irrigation (not common in YBRGGW)
* Erosion (exposes sodic subsoil = $\uparrow$ in salinity, $\downarrow$ in organic matter, $\downarrow$ in watertable depth)
* Remediation activities

Table 2: Summary of the main influences and considerations when researching biodiversity.

* “What used to be there?” (Benchmarks?)
* “What’s there now?” and “What should be there now?”
* Dynamic state (spatially and temporally)
* Seasonal, long/short term climatic influences, cycles, fluctuations (drought, storms, frost, wind, exposure)
* ‘Climate change’ (temp’ extremes and $\uparrow$ in CO_2)
* Geology (lithology, structures) - heterogeneous
* Soils/regolith (physical, chemical, biological properties) - heterogeneous
* Topographic setting - position/proximity in landscape
* Fire (intensity, frequency and season)
* Site size and quality (scale - moisture, light, temp)
* Edge effects (salinity, grazing/clearing, roads, storms)
* Life cycle, trophic level, range size, mobility, dispersal/vagility, specialist/generalist, recruitment, competition, succession, adaptability, resilience, morphology, fertility, fecundity, genetic variation
* Dieback (natural/ human induced), mistletoe
* Anthropogenic disturbances (past and present)
* Grazing (Sheep, cattle, horses, goats etc)
* Vegetation clearing and ‘tidying up’
* Cropping, plantings and fencing
* Fertilisers, herbicides, insecticides, pollution
* Roads and tracks
* Fire and firewood collection
* Ferals - animals (foxes, rabbits, cats) and weeds
* Salinity (secondary or primary) – depth, levels
* Remediation activities

SALT, PLANTS AND BIODIVERSITY

Many factors can influence biodiversity and ecosystem function (see Table 2). Table 3 summarises the effects of salinity on vegetation, both directly and indirectly. Direct effects include altered osmotic gradients and toxicity factors. Different factors can adversely affect biochemical, molecular and physiological processes and different life stages of the plant, such as germination, growth, reproduction and senescence (Lauchli & Epstein 1990, Rengasamy *et al.* 2003). All of these factors vary spatially (vertically and horizontally) and temporally. One cannot assume that adverse effects on particular plants will be detrimental to the sites overall biodiversity or ecosystem health. Thresholds are important and need to be considered (Barnett 2000, Cramer & Hobbs 2005). Hasegawa *et al.* (1994) suggest glycophytes (non halophytes) can adapt to high levels of salinity, provided that stress imposition occurs in moderate increments. Briggs & Taws (2003) suggest salinity encourages weeds and kills native vegetation and Zeppel *et al.* (2003) suggest many threatened fauna and flora species are at risk to increasing salinisation. ANZECC (2001) indicated that the quantification of the potential impact of dryland salinity on biodiversity, particularly on those species that are faced with extinction, is a high-priority area of research that requires immediate attention.

It is likely that salinity does not *directly* affect terrestrial fauna, however, indirect effects clearly include any reduction in vegetation condition and subsequent habitat health.

Table 3: Summary of the possible effects of increasing salinity on plants. Different factors can adversely affect biochemical, molecular and physiological processes at different life stages of the plant, such as germination, growth, reproduction and senescence.

Direct	Osmotic effects Toxicity effects – (Na and Cl, plus changes to K, Al, B, Fe, Ca, Mg, HCO_3, CO_3, SO_4, NO_3)
Indirect	Soil structure degradation Reduced soil infiltration (porosity and permeability) Reduced soil organic matter Reduced soil microbial activity and soil ecology Changes to soil pH and Eh Susceptibility to waterlogging and erosion Susceptibility to diseases and pathogens Susceptibility to insect and herbivore attack (dieback)

SITE SELECTION AND METHODOLOGY

More than 200 sites were inspected, of which 10 were chosen for this research. The majority of sites are located on Travelling Stock Reserves, managed by the NSW Rural Lands Protection Board (TSRs) and are surrounded by agricultural land. Although many private land sites were visited, it was considered they were unsuitable for this research owing to past landuse management practices, particularly intensive grazing. Table 4 summarises the methodology adopted. An holistic approach was essential to identify the fundamental processes acting upon the system and both biotic and abiotic measurements were taken which focused on the regolith. Select measurements were taken at various times of the year to account for seasonal variation.

Table 4: Summary of current research methodology, using biotic and abiotic measurements.

Measurement	Field	Laboratory
Abiotic	EM31 & EM38, EC (1:5), TDS, pH, texture, colour, pans and horizons, structure, infiltration, penetration, organic matter	soil cation and anion analysis (CEC, SAR, ESP, SPAR, ESI), total N, P, dispersibility, bulk density
Biotic	microbial respiration, termite surveys, vegetation condition and species present, ground macro-invertebrates, (log discs pitfall traps), worms, Landscape Function Analysis, Habitat Hectares, leaf porosity & photosynthetic rate	leaf cation and anion analysis, total N and P. Nematodes

PRELIMINARY RESULTS

Qualitative

The majority of dryland salinity sites on the Southern Tablelands of NSW (STNSW) are relatively small, generally less than a few hectares. Many native grasses, in addition to eucalypt species, are to be found growing either directly on or near sites with increased salinity and appear to be in good condition. It is likely native species have adaptations to combat increased salinisation, especially those occupying lower elevations. Some trees are in poor health although the reasons for this could be many (see Tables 2 and 3), and may have nothing to do with increased salinity. It is probable that the soil seed banks within eroded scalds are minimal or non-existent. The main influences affecting terrestrial biodiversity in the YBRGGW appear to be exotic species such as foxes and rabbits, intensive grazing, natural events such as the current drought, and past landuse practices including land clearing and fragmentation. In many cases, increased salinisation may only be a minor *additional* stress.

Dieback is a significant confounding variable commonly associated with box/gum woodlands in the STNSW. Dieback, both natural and/or human induced, occurs at salinised and non salinised sites. The recent drought is also likely to affect vegetation, and exhibits similar symptoms as dieback and salinity.

Dryland salinity appears to be influenced by geology, faults and lithology changes which control water pathways (e.g., Clarke *et al*. 1999), and by lithology type directly contributing salts. Roads and tracks constrict water pathways and play a significant role in many outbreaks. Most sites are associated with intensive grazing and appear to respond to grazing exclusion and management practices.

Quantitative

Results indicate salinity is highly variable both spatially and temporally. Salinity levels at saline sites are generally relatively low, rarely exceeding 10 ds/m at the surface, where the salinity is usually the highest.

Levels vary significantly with depth and across small horizontal distances (often < 1 m), even within scalds. These levels vary also with rainfall. Infiltration rates within and between sites are highly heterogeneous, with clear implications for so-called *recharge* and *discharge*. Survey results also indicate that many invertebrates tolerate, or in some cases, appear to favour increased salinity. Current analyses suggests that bulk soil electrical conductivity (EM31 and EM38), may be useful for salinity mapping and indeed mitigation and remediation activities, however, geological and regolith complexities and confounding variables such as the soil clay, moisture, ion and mineral content must be considered.

DISCUSSION

Dryland salinity on the STNSW is a complex problem. Investigating the effects of increasing salinity on terrestrial biodiversity introduces many complexities and problems that require careful consideration. An holistic, multidisciplinary approach is necessary to identify fundamental processes. Many biotic and abiotic measurements need to be taken at different times of the year, and at different depths of the soil profile. Assessments need to be done at a site scale rather than at a catchment scale. Salinity cannot be treated as a single factor and many other factors need to be investigated. Confounding variables such as dieback, soil degradation (predominantly caused from excessive grazing) and drought can cause plants to exhibit similar symptoms to those caused by excessive salinity.

The majority of dryland salinity sites in the STNSW are associated with excessive grazing and subsequent soil degradation, not rising watertables associated with perennial vegetation removal. Salinised sites are generally eroded with exposed sodic subsoils (B horizons) which effectively reduces the depth to the watertable, increases the salinity and dispersibility at the surface, decreases organic matter, microbial activity and infiltration and increases bulk density. Increased soil temperatures and wind erosion from exposure also occurs.

Many sites inspected also contain a diverse range of endemic species, which appear to be tolerating the salinity. Further work is required to determine tolerant native perennial species which can be used for fodder production, increased biodiversity and other environmental, economic and social benefits.

Table 5 summarises the problems and opportunities for dryland salinity remediation in the STNSW. Although problems exist, it is considered that there are many opportunities for successful remediation activities.

Table 5: Summary of problems and opportunities for dryland salinity remediation and mitigation in the STNSW.

Problems	Opportunities
• Primary or secondary?	• Small size of actual saline sites
• Accepted ‘rising watertable’ model.	• Generally low salinity levels at many saline sites.
• Uncertainty as to the cause and source	• Highly variable salinity (spatial and temporal)
• Climate and drought	• Salt tolerance of flora and fauna native species
• Dieback	• Capability of vegetation regeneration
• Grazing	• Increased biodiversity, soil health, water quality
• Roads and tracks	• Convert liability into an asset (profitability)
• Erosion, soil degradation	• Not associated with rising water tables
• Economic constraints	• Funding opportunities

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Acknowledgements: The CRC LEME and the Southern Tablelands Farm Forestry Network for stipend funds; Colin Pain from GA; David Tongway, Theo Evans, Mike Hodda and Geoff Baker from CSIRO; Nico Marcar from the CRC PBMDS; Peter Brown and Kevin Baker from the NSW RLPB; Nik Henry, Bill Semple, David Russell and Don Stazic from DIPNR; Rachel Nanson from UNSW@ADFA, John Spring from BRS; Brian Tunstall from NRI; Brad Parker from MCMA; David Hilhorst from LCMA; Mauro Devanzo from ANU; and Stephen Rymer from ACT Forests are all acknowledged and thanked.