# The use of native (endemic) grass and tree species for dryland salinity mitigation, remediation and agronomy activities in south-east Australia

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**Abstract**

Dryland salinity is perceived as a serious environmental, economic and social threat in south eastern Australia, and consequently receives a high priority on the political agenda. Much funding has been directed towards secondary salinity mitigation and remediation activities that mainly focus on planting exotic species. Despite the occurrence of primary salinity in southern Australia over millennia, and the consequent adaptation of endemic plants to these conditions, endemic species are generally not utilised in salinity management.

In contrast to Western Australian salinised sites, those on the Southern Tablelands of New South Wales (STNSW), the midlands of Tasmania and the Hunter Valley of NSW are generally small and localised. Mitigation and remediation activities on these sites that combine necessary soil works with stock grazing control frequently allow regeneration and recovery of native grasses and trees to occur relatively quickly. At least six perennial native fodder grasses, and two native eucalypts (*Eucalyptus melliodora* and *E. blakelyi*), were able to colonise and persist at sites with increased salinity levels on the STNSW, at all stages of their life cycles. This is encouraging for the Yellow Box Red Gum Grassy Woodlands that are listed as an Endangered Ecological Community in both State and Federal Acts.

This paper identifies and discusses remediation activities, fodder production and farm forestry on salinised STNSW sites using these native species. The potential for positive environmental, economic and social changes at these sites through remediation using these native plant species is high. We suggest that the use of the long-stem tube-stock technique should also receive a high priority for future tree revegetation trials.

**Key Words**

Salinisation, perennial, fodder production, Eucalyptus, agroforestry

## Introduction

Dryland salinity is reported to be a serious threat to biodiversity (ANZECC 2002), land, water and infrastructure in south eastern Australia (NLWRA 2001; DPI 2005). However, Australia is one of the saltiest continents on earth (Ghassemi et al. 1995) and primary salinity is not a recent phenomenon (Tadeauz 1989, Crowley 1994). As a result, it has the highest proportion of saline and sodic soils in the world (Sumner and Naidu 1998). We suggest that it is therefore probable that some native flora and fauna species do have the necessary adaptations to combat and possibly exploit salinised environments.

Previous limited research has suggested that endemic flora does not tolerate salinised conditions. In eastern Australia, salinity is reported to actually favour exotic species whilst inhibiting both the presence and growth of many natives (Taws 2003; Briggs and Taws 2003; Thompson and Briggs 2005). There has been more intensive research conducted in southern Western Australia with similar results (e.g. George et al. 1995; Keighery et al. 2004). Although Taws (2003), Briggs and Taws (2003) and Thompson and Briggs (2005) conclude that increased salinity levels adversely affect woodland biodiversity in south-eastern Australia, however, no objective evidence is provided. Their qualitative evidence is also inconclusive as the experimental design does not consider many important factors that will also affect plant growth and persistence. In addition to salinity, such factors may include soil degradation and soil structure decline, increased or reduced soil pH and nutrient availability, and reduced opportunities for plant recruitment. Furthermore, the link that these authors propose between eucalypt dieback (Heatwole and Lowman 1986; Landsberg et al. 1990), or tree health decline, and adverse effects of soil salinity at the study sites is unfounded. In previous work by Taws (2003), Briggs and Taws (2003) and Thompson and Briggs (2005), dieback is given a psuedo-quantitative measurement (adapted from Heatwole and Lowman 1986) by observing the visible and variable signs of tree 'health'; soil salinity was often measured from a single soil sample taken peripherally from each site. Both of these issues are more complex. Dieback is common across the whole of the landscape and is rarely the result of increased salinity levels (Landsberg et al. 1990; Turner and Lambert 2005). The front cover of Taws' (2003) report shows a salinised site with dead trees, which are reportedly the result of secondary salinity mortality (dieback). Closer inspection reveals that the trees at this site have actually been ringbarked. Most of the sites have been, or are intensively grazed by stock and suffer from past and present degrading activities, but the likely effects of this on soils and vegetation were not considered. Soil salinity is highly variable both temporally and spatially (horizontally and vertically), within and between sites, necessitating extensive soil sampling (Semple et al. 2006). Soil beneath trees should be analysed if salinity levels are to be linked to tree mortality, not somewhere nearby. As salinity levels also vary considerably temporally, especially following rainfall, strategic sample timing is therefore required to account for this variation. Taws (2003) and Briggs and Taws (2003) base their arguments on a feedback model that describes 'rising groundwater', causing secondary salinisation, which kills the trees, and thereby allows the groundwater to 'rise' even further, killing more trees, and so on (ANZECC 2002). However, no evidence is provided for rising groundwater and Dahlhaus et al. (2000), Acworth and Jankowski (2001), Wagner (2001; 2005), and Bann and Field (2005; 2006a) all argue that the application of the rising groundwater model in many upland landscapes in south-eastern Australia is inappropriate. In addition, Barnett (2000) and Bann and Field (2005) suggest that salinised landscapes and ecosystems on the Southern Tablelands of NSW (STNSW) are indeed functional.

Many different types of salts occur naturally in the Australian landscape and many of these are essential for plant growth. However, NaCl is the focus of most salinity research. This is appropriate, considering its abundance and the multitude of direct (toxicities, osmotic gradients) and indirect (e.g. soil structure decline) adverse affects that it has on plants (e.g. Bernstein 1975; Marcar et al. 1995; Barrett-Leonard 2003; Botella et al. 2005). Plant salt sensitivity and tolerance is dependant upon life stage; adult plants are often more capable of tolerating increased salinity levels than juveniles or seedlings (Bernstein 1975). It is therefore fundamental to understand salt sensitivity and tolerance levels for individual species, including growth history variations, to manage and remediate disturbed salinised ecosystems. An understanding of the ecosystem thresholds and response to salinity is also essential (Cramer and Hobbs 2005). Botella et al. (2005) suggest that all plants are able to tolerate some degree of salt stress and that those indigenous to saline environments have substantially greater stress adaptation capacity. A large number of salt regulated genes (those responsible for salt tolerance) provide indication that plant salt adaptation is multifaceted and the response to salt stress is very complex, however, direct functional evidence is required (Botella et al. 2005). However, there is a minimal understanding on how salinity and other abiotic stresses affect the most fundamental processes of cellular function, including cell division, differentiation and expansion. These functions have a substantial impact on plant growth and development (Hasegawa et al. 2000). Indeed, Hasegawa et al. (2000) suggest glycophytes could adapt to high levels of salinity, if it develops in moderate increments.

The grass species commonly used for salinity mitigation and remediation activities in south-eastern Australia include tall wheat grass (*Thinopyrum ponticum*), puccinellia (*Puccinellia ciliata*), and perennial ryegrass (*Lolium perenne*) (DPI 2005). However, Semple et al. (2003) indicate that these species do not perform well at all sites and tall wheat grass has the potential to escape from sites and to become an environmental weed (e.g. Elias 2002). In addition, puccinellia does not like acidic soils (Semple et al. 2003). Although some research indicates that these native grasses are indeed relatively salt tolerant (Semple et al. 1994) and are useful for salinity NRM activities (e.g. Wagner 2001; Semple et al. 2002), they are largely overlooked as alternatives to the exotics. Trees often consist of eucalypt hybrids and/or West/South Australian species (e.g. Pepper and Craig 1986; Schofield 1992; Marcar et al. 2000; Harwood and Bush 2002) rather than local endemic species. We have excluded halophytes from this paper as none were identified at the sites inspected.

The aim of this paper is to address the current misconception that exotic species should be a high priority for the management of dryland salinity occurrences in south-east Australia. We will support this suggestion with examples of perennial native grasses and tree species that tolerate the salinised conditions that occur on dryland salinity sites on the STNSW.
Dryland salinity is considered the major environmental threat in the Yass/Boorowa region of the STNSW and is apparently increasing at an alarming rate (MDBMC 1999).

**Methods**

*Study area*
Many sites in south east Australia were inspected and 10 were identified on the STNSW in the Lachlan/Murrumbidgee River Catchments (Murray Darling Basin) for intensive research into dryland salinity geophysical and biophysical processes. Sites identified were mainly Travelling Stock Reserves (TSRs) managed by the NSW Rural Lands Protection Boards, and were chosen within or immediately adjacent to Yellow Box (*Eucalyptus melliodora*) Red Gum (*E. blakelyi*) Grassy Woodlands (YBRGGW) (see Figures 1 and 2). Many TSRs suffer from relatively little degradation, particularly when compared with private land. These woodlands are listed as an Endangered Ecological Community (EEC) in both State and Federal Acts. The YBRGGW were far more extensive on the lower slopes of the STNSW prior to clearing for agricultural practices. In addition, they have the misfortune of occupying the same areas, where dryland salinity is often expressed. The region has a non-seasonal, average annual rainfall of approximately 550-700mm, although this varies considerably (211-1230mm/yr at Yass in past 120 years - BOM 2005). Intensive grazing (primarily sheep) and winter cropping (cereals) are the main agronomy practices in the region. Sodic duplex soils predominate, especially on the lower slopes and drainages where dryland salinity usually occurs. Dryland salinity is reported as being a major threat to agronomy practices. Geology was purposefully restricted to the Ordovician and Silurian metasediments and volcanics of the Lachlan Fold Belt.

*Measurements*
As the relationship between salinity, soils and vegetation is complex, a multidisciplinary approach was adopted which utilised various biotic and abiotic methods. These included measurement of vegetation, soil biota and soil properties such as: Landscape Function Analysis, soil hydrology (e.g. infiltration and runoff rates, slakeness), pH (performed in the laboratory and the field), EC (1:5 soil:water), EM38 and EM31 (bulk ground-based electromagnetic induction instruments which are a surrogate measurement for salinity), total N, and exchangeable cations, bulk soil microbial respiration, total fungi and bacteria counts, piezometer monitoring, and a number of flora and fauna surveys. Measurements were conducted at strategic times from 2004-2006. Vegetation 'health' was quantified using a PEAmeter (Photosynthesis Efficiency Analyser meter), a hand held instrument that quantifies photosynthesis by measuring Photosystem II rapidly and reliably (Liu et al. 2004). This was performed on *E. melliodora* leaves during spring of 2005.

**Results and discussion**
Electrical conductivity (EC 1:5 soil:water) and electromagnetic induction results (EM38 and EM31) indicate that salinity is highly variable, both spatially (vertically and horizontally) and temporally, especially following rainfall. The highest salinity levels (EC 1:5) generally occur at the soil surface (loams). The maximum level obtained during monitoring was 20.2 dS/m (surface), however, the same location reduced to 1.6 dS/m two days later, following rainfall (illustrated at site in Figure 2). Much lower levels of <5 dS/m were more typical. The maximum water salinity measured within peizometers was 5.6 dS/m (obtained at the site with highest soil EC), although levels were also usually much lower (<3 dS/m). Surface water measurements did not exceed 5 dS/m at any site over the two years monitoring and were generally less than 2 dS/m. This suggests that tree root systems are unlikely to be affected by salinity at these sites. Soil pH levels in the salinised areas (scalds) ranged from acidic (pH ~4) to highly alkaline (pH 9 - 11.2) in $H_2O$ and abruptly approached neutral in the adjacent grassy woodlands (often <1m distance) which contain humic AO/A1 horizons. This suggests alkalinity is a major factor for vegetation, including reducing nutrient availability. Further analyses are being done to investigate these results. Table 1 summarises measurements.

Observations indicated eucalypt dieback is a significant phenomenon on the STNSW and occurs in all parts of the landscape, not exclusively the areas that are possibly affected with increased salinity. The causes of dieback are attributed to many factors including root fungus, insect attack (above and below ground), soil degradation (e.g. soil structure decline and changes to nutrient levels and pH), senescence, nutrient increase or depletion, drought and reduced soil moisture availability (Landsberg et al 1990; Turner and Lambert 2005), in addition to ringbarking (G. Bann pers. obs.). Once health decline is initiated, outbreaks are likely to be associated with numerous interacting factors, variables and feedback loops (Turner and Lambert 2005). The lack of literature on the spread of various types of dieback limits the capacity to understand causal mechanisms, and therefore achieve management solutions and/or resolution. Moreover, the visual effects of drought and increased salinity on trees are similar, making differentiation problematic.

Table 1. Results summary showing differences between grassy woodlands and salinised sites (scalds) on the STNSW.

| **Parameter** | **Grassy woodlands (grasslands)** | **Scalds** |
|---|---|---|
| Soil bulk microbial respiration ($CO_2$) | High | Low |
| Soil infiltration rates | High (but variable) | Low (but variable) |
| Soil pH | slightly acidic to neutral | Acidic to extremely alkaline |
| Soil structure | Good to very good | Very poor to poor |
| A0 and A1 horizons | Usually present | Usually absent |
| Soil EC (1:5 soil:water) and EM38/31 | Low to Medium | Low to High |
| Soil surface sealing | Low | Low to Very High |
| Soil surface dispersibility | Low | Low to Very High |
| Runoff | Low to High | Low to Very High |
| Erosion | Low | High (but variable) |
| Photosynthesis - *E. melliodora* leaves | High | High |
| Macro-invertebrates | Med to High no's and diversity | Low to High no's with low diversity |

**Figure 1. Localised saline site showing healthy young and mature *E. melliodora, E. blakelyi* and native perennial grasses (grazed by kangaroos and wallabies). The two dead trees have been ringbarked. Note possum den in horizontal log left centre of photo.**

**Figure 2. Localised saline site with severe soil degradation and native perennial grasses. This site gave a soil surface EC (1:5) measurement of 20.2 dS/m which reduced to 1.6 dS/m two days later, following rainfall. Note the surface salt to the right of the photo and the abrupt boundary between scald and grasses. Drainage from the site is directed into healthy grassy woodlands, unaffected by the salinity.**

Productive endemic grasses found growing within and surrounding salinised scalds included: Themeda australis (syn T. triandra), Austrodanthonia spp., Chloris truncata, Bothriochloa macra, Sporobolus creber, Cynodon dactylon, Elymus scaber and Dichelachne micrantha. Table 2 summarises these grasses, where they were found growing and their productivity potential. A number of other species were identified but excluded from this paper as they are considered unproductive as fodder. A sharply defined boundary between the scald and the grasses was usually present. As many native perennial grasses are drought (and salt) tolerant (Wheeler et al. 2002), do not require fertilisers, are warm and cool season growing, grow as thick tussocks with deep root systems and provide habitat for epigaeic species (Wheeler et al. 2002), their abundance and use at these sites is encouraging for agronomy and conservation purposes. More desirable outcomes can be achieved using large, native, perennial tussock grasses which can effectively capture organic matter and nutrients moving over the soil surface, as they incorporate greater biomass (roots and litter) into the soil than small annual species (Derner et al. 1997). Cynodon dactylon offer additional advantages for scald recovery by having rhizomes capable of growing onto and across the scald, without the need for germination directly within the scald.

Endemic trees included E. melliodora, E. blakelyi and E. cinerea. The E. melliodora appear to be dieback resistant (i.e. does not show signs of widespread excessive insect attack or health decline) whilst E.

blakelyi were observed to be dieback susceptible, although E. blakelyi do appear to be capable of regeneration after considerable rainfall, indicating the dieback may be at least partially the result of drought. E. melliodora exhibits a highly variable phenotype, with bark ranging from entirely smooth (‘gum’ type) to entirely rough (‘box’ or ‘mahogany’ type). This may suggest the possibility of a genotype with adaptive capabilities, including the exploitation of primary and secondary salinised environments.

All life stages of both grasses and trees were observed growing on salinised sites. Scalds were usually devoid of vegetation (illustrated in figure 2), however, the lack of vegetative cover is quite likely to be the consequence of other unfavourable soil factors, including changes to pH such as extreme alkalinity (up to 11.2), increased bulk density and soil structure decline, soil organic matter decline and changes to soil microbial composition. Moreover, exposure and the likelihood of a reduced seed bank due to the highly dispersible, sodic, erosive soil surfaces, without an A0/A1 horizon, would reduce the potential for seed germination at most scalds.

**Table 2 - Native grasses identified growing at salinised sites on the Southern Tablelands of NSW. †**

| Grass | Common name | Growth | Pasture potential | Comments* |
|---|---|---|---|---|
| *Bothriochloa macra* | Red-leg grass | N | √√ | Drought tolerant, low nutrient soils. ‘Warm season’ growing, uncommon |
| *Chloris truncata* | Windmill grass | S | √√√ | Hardy, warm season native pasture grass. Common on degraded sites and heavy soils. Salt tolerant. |
| *Cynodon dactylon* | Couch grass | S | √√√ | Vigorous native? Very hardy, drought and salt tolerant. Warm season. |
| *Austrodanthonia spp.* | Wallaby grasses | S | √√√ | Hardy, common and salt tolerant. Productive most of the year with high potential. A number of possible species. |
| *Dichelachne micrantha* | Short hair plume grass | A | √ | ‘Cool season’ grass, probably useful as pasture grass. Uncommon |
| *Elymus scaber* | Wheat grass | N | √√√ | Drought and salt tolerant. Young growth very palatable but does not like heavy grazing. Cool season. Common. |
| *Sporobolus creber* | Slender rats-tail grass | N | √ | Summer and autumn growing grass (‘year long green’). Uncommon |
| *Themeda australis (Syn T. triandra)* | Kangaroo grass | A | √√ | Does not like heavy grazing. Warm season Young growth palatable. Very common |

† Information collected from personal observation, Bill Semple (pers. comm.) and references below. Only the spp. considered reasonably useful for fodder have been included. All species are perennial growing although *Chloris truncata* is often biennial. Growth: S – grows on scalds; A – grows adjacent to scalds; N – grows nearby scalds (growing within 5-10m)
*Note that all species require strategic grazing management regimes, usually to prevent excessive grazing and over-mature growth forming. The majority of perennials are tussock forming and the new growth is considered very palatable. Cool season species are often referred to as ‘year-long green’ (depending on rainfall) (B. Semple pers. comm.).
References: Lamp CA, Forbes SJ and Cade JW (2001); Wheeler DJB, Jacobs SWL and Whalley RDB (2002).

Vegetation health quantified with the PEAmeter indicated *E. melliodora* were *not* adversely affected by increased salinity levels, or rising groundwater. No significant difference was found in Photosystem II measurements between trees growing in non saline and those growing in saline environments.

Saline sites inspected on the STNSW are typically localised, generally <2 ha in size (Wagner 2001; 2005; Bann and Field 2005), associated with intensive stock grazing and soil degradation (Bann and Field 2006a,b), and seasonally variable (Wagner 2001; Bann and Field 2005). All scalds were associated with erosive, dispersible (sodic) A2 and B horizons and effectively very little productivity (illustrated in Figure 2). It appears that soil degradation subsequent to stock grazing is the predominant cause of salinisation in these upland landscapes (Bann and Field 2005, 2006a,b). Stock selectively remove vegetation and compact the soil, thereby increasing surface sealing, density and runoff whilst decreasing soil organic matter and nutrients (Yates et al. 2000), which effectively allows increased evaporation and salinity. Observations indicated that fencing and stock exclusion, in combination with appropriate soil works, has allowed vegetation regeneration and landscape recovery at most salinised study sites. The localised nature of outbreaks on the STNSW indicates the potential for remediation and relatively rapid recovery. No sites were observed to increase in size or severity during the three years research, which agrees with the results of Wagner (2001, 2005), who studied 90 salinised sites in south east NSW.

Farm agroforestry is becoming an important activity on the STNSW (Webb 2000; Harwood and Bush 2002), with many likely benefits. The supposed benefits of revegetating saline land include carbon sequestration, erosion control, flood mitigation, improved wildlife habitat, increased soil organic matter, improved aesthetics and water use (Malcolm 2005). Sites with plantations and revegetation immediately adjacent to the salinised areas were observed to have better quality soils than the adjacent soils devoid of woody vegetation. Large scale adoption of perennial plant-based farming systems, especially farm forestry, has the potential to improve the prospects for native biodiversity (Salt et al. 2004). The retaining of existing *E. melliodora*, in addition to planting trees, provides many benefits, including biodiversity conservation (EEC) and supplying habitat for many rare and threatened species (Gibbons and Boak 2002), honey and timber production (*E. melliodora* being termite and dieback resistant) (Boland et al. 1984) and aesthetics. Moreover, young *E. blakelyi* appear to be less affected by dieback, such as severe insect leaf attack, when growing beneath *E. melliodora*.

Long stem tube stock is an innovative propagating method originally used for riparian revegetation in the Hunter Valley (Hicks et al. 1999). Tube-stock are strategically propagated to procure a healthy extended stem. This allows transplantation to a greater depth in the soil (usually 60-90cm depth), with the following advantages; a) the roots are less likely to suffer from desiccation and temperature extremes; b) the roots are less likely to suffer from groundcover competition, c) plants are more likely to develop a substantial root system (roots develop from leaf nodes) and d) plants are less likely to be adversely affected from soil removal during erosion processes. It is therefore likely that long-stem tubestock are likely to be beneficial in salinised areas (Hicks 2003), as the increased levels of soil salt are contained within the soil surface (crust) and ongoing surface erosion is unlikely to harm their deep roots.

**Conclusion**

Although current natural resource management and agronomy activities focus on the use of exotic species for addressing dryland salinity, we conclude that many native (endemic) grasses and trees appear to tolerate increased salinity levels on the STNSW. These warm and cool season native grasses include a number of reasonably productive species and have the advantages of being drought (and salt) tolerant, do not require fertilisers, and are deep rooted, tussock forming perennials. Salinised sites are generally small and localised, and fencing and stock control promotes both native grass and tree regeneration. This is a positive outcome for the conservation of YBRGGW (EEC) of eastern Australia, for mitigation and remediation of salinised sites, for profitable agronomy activities including fodder production and agroforestry. The possibilities of turning a liability (an unproductive scald) into an asset must also be considered.

We conclude that more trials need to be undertaken to investigate the use of endemic grass and tree species for salinity mitigation and remediation in south-eastern Australia. As the increased salinity levels within the soil profile at salinised sites are usually concentrated within the surface layer, and erosion is often a significant problem at scalds, trials with the long-stem tubestock tree planting method could be useful.

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