SALT SOURCES AND DEVELOPMENT OF THE REGOLITH SALT STORE IN THE UPPER BILLABONG CREEK CATCHMENT, S.E. NSW

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Australia has the largest ratio of salt-affected soils with respect to total surface area of any continent in the world. The processes of dryland salinity (which results from an increase in salts in solution) and consequent sodicity (where the soil complexes have high levels of adsorbed Na^+, i.e. exchangeable sodium percentages ≥ 6) are major land and water degradation issues, particularly within the Murray-Darling Basin. In the catchments of southeast New South Wales such processes significantly impact on both agricultural production and water quality in the river systems. While the sources of salt found in the landscape have been debated by many workers, the general consensus is that the major contribution comes from precipitation, although attempts at direct comparison against other potential sources such as mineral weathering or aeolian dust are few in eastern Australia.

This study assessed the contributions of various salt sources of the regolith in the Upper Billabong Creek Catchment (UBCC) of southeast New South Wales, and how these salts are stored and released in the environment. Such information is valuable in land and water resource decision-making, both within the catchment and in similar environments in neighbouring catchments, particularly with regards to prominent environmental issues such as soil sodicity, waterlogging and dryland salinity (Woodward-Clyde 1999, NLWRA 2001).

The UBCC is located between the Murrumbidgee and Murray River catchments in southeast NSW (Figure 1). Covering an area of approximately 300,000 ha upstream of Walbundrie, the catchment provides a transect from the Riverine Plain in the west to the bedrock-dominated uplands of the Western Slopes in the east. A comparative study of two sub-catchments from the respective ends of the catchment, Simmons Creek in the west and Ten Mile Creek in the east (Figure 2), has revealed similarities in the origin of the regolith materials, which includes a significant aeolian component. Variation in the evolution of these materials has occurred as a result of different landform and climatic conditions, and plays a significant role in the distribution of salts in the landscape.

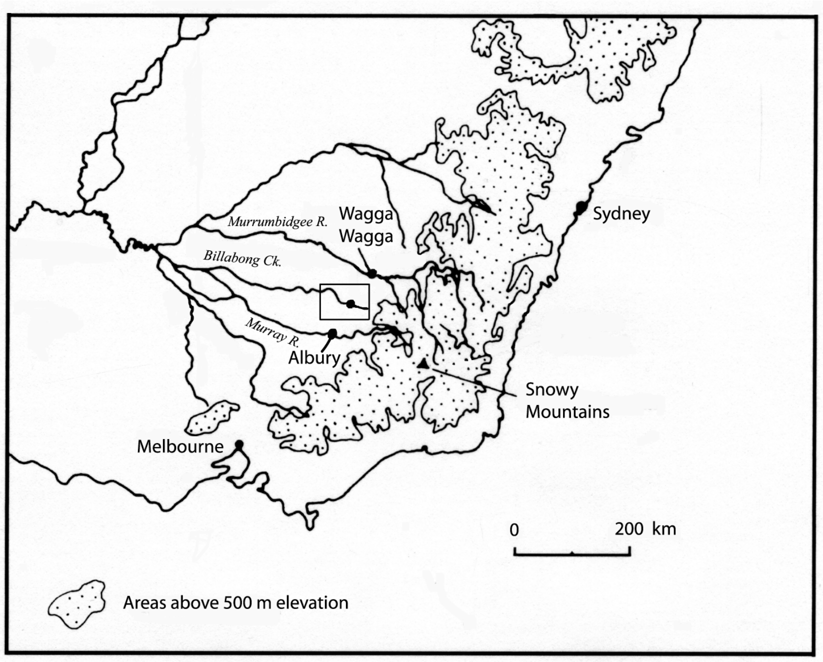

Figure 1: Location map of the Upper Billabong Creek Catchment study area (after Chen *et al.* 2002).

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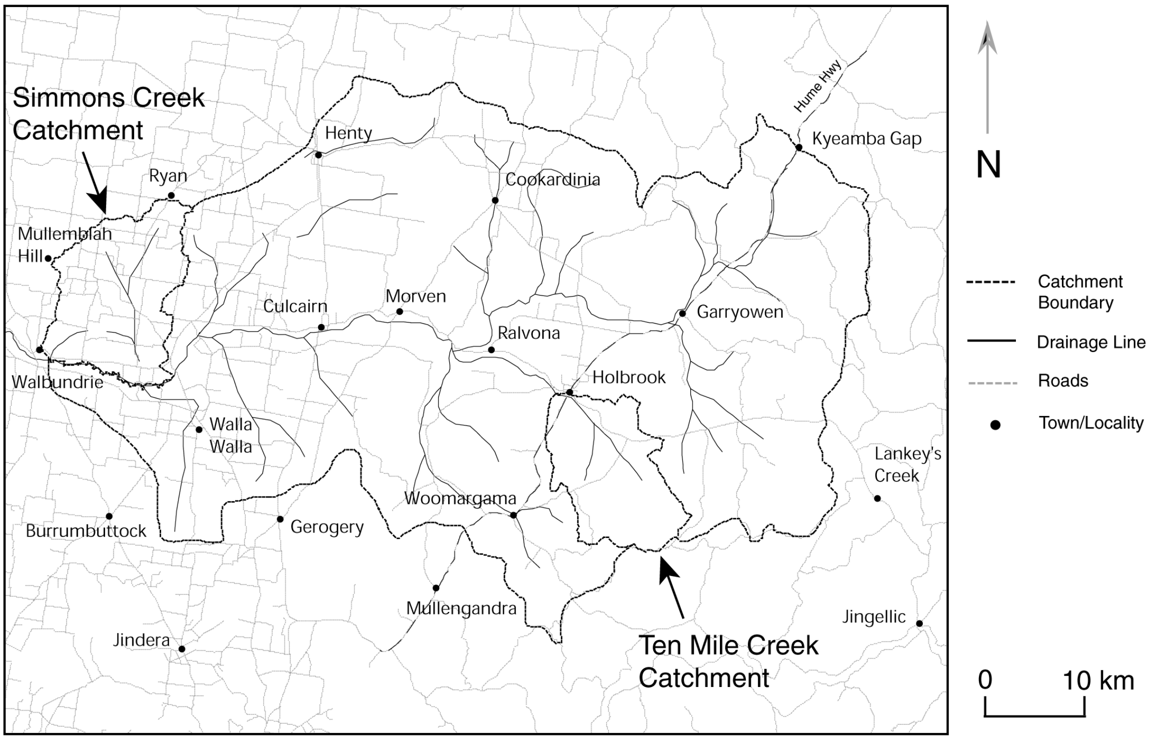

Figure 2: Upper Billabong Creek Catchment showing Ten Mile Creek and Simmons Creek sub-catchments (after Glen *et al.* 1997).

Despite climatic variability through the Quaternary, there has been a shift from dust as the significant source of soluble salts to a generally precipitation-dominated supply since the Late Pleistocene (Hesse & McTainsh 1999). Results from the present study indicate that precipitation is the current dominant soluble salt source, contributing over 1 million times more salt than rock weathering, and up to 200 times more than that from calculated aeolian dust inputs on an annual basis. Precipitation has a discernible marine signature along with a minor terrestrial dust component, and is subject to appreciable contamination from local anthropogenic sources such as soil ameliorants and fires.

Existing models for the development of land and water degradation processes such as salinity have placed a heavy emphasis on water movement, but they do not account sufficiently for the role of regolith in storage and distribution of salts within the landscape. In southeast New South Wales, aeolian materials have been prominent in landscape evolution, particularly throughout the Quaternary. Parna (an aeolian clay transported primarily as silt-sized aggregates - Butler 1956) is found in landscapes of the Wagga Wagga region (Butler & Hutton 1956, Chen 2001, Chen *et al.* 2002), the Southern Tablelands (Broughton 1992, Melis & Acworth 2001) and the Riverine Plain (Van Dijk 1958, Churchward 1963). This material is thought to have carried appreciable quantities of salt (Bowler 1976, Evans 1998, Melis & Acworth 2001). The morphology of the landscape upon which parna was initially deposited, and its present distribution predominantly on lower angle landforms, exerts a major control on the evolution of the regolith. In the UBCC, where the presence of parna in the landscape has been confirmed, both leaching and accumulating environments are observed.

To assess the characteristics of these two environments within the UBCC, detailed investigations of the upland Ten Mile Creek and lowland Simmons Creek Catchments were conducted. The distribution and variation of regolith materials across the landscape has been determined by regolith-landform mapping. Colluvial and alluvial deposits, with minor occurrences of *in situ* materials, dominate landforms in the UBCC. Materials found on low angle landforms (<6% slope) commonly contain large quantities of silts and clays, identified by morphological and particle size characteristics as parna. In contrast, alluvial, colluvial and *in situ* materials characteristically contain appreciable quantities of predominantly quartzose sand.

In higher landscape positions, or on landforms where slopes exceed ~3% and parna has either been preserved or reworked by hillslope erosional processes, the regolith materials are well leached and hold little salt. Consequently parna, where it remains in the landscape, tends to retain its original particle size distribution in the silt to clay size ranges. Materials are generally characterised by acid to neutral pH, exchange complexes dominated by Mg^{2+} and Ca^{2+} with little Na^+, and abundant Fe-oxides. These properties result in well structured, freely draining soils that permit rapid through-flow of percolating meteoric waters. As a result, these are areas of significance to groundwater recharge.

Such a high relief environment is typified by the upland Ten Mile Creek Catchment, where significant exposed bedrock and areas of steeper slopes generally provide leaching conditions, and as such the majority of salts are removed into the deeper groundwater and out of the catchment. Small areas of lower angle landforms containing parna are characterised by sodic regolith, with very localised salinity outbreaks and waterlogging showing a seasonal dependence. Assuming an entirely atmospheric input, salt accumulation rates and stored salt masses in the Ten Mile Creek Catchment are greater in the unsaturated zone than in the groundwater, with the greatest salt concentrations found in the deeper groundwater.

Conversely, in lower relief landscapes or on low angle landforms in the UBCC, conditions conducive to salt accumulation develop. Dominant silt and clay particle size fractions and low gradients in these landscape positions are responsible for low hydraulic conductivities and poor drainage. This restricted drainage promotes ion exchange, accumulation of excess Na^+ on clay exchange complexes (causing sodicity), and may lead to dispersion of parna aggregates and an apparent increase in clay content. Materials are characterised by neutral to generally alkaline pH, exchange complexes dominated by Mg^{2+} with significant Na^+ and minor sesquioxides leading to poorly structured, impermeable soils that restrict drainage of percolating meteoric waters to the groundwater. Under these conditions salts accumulate in solution, and proximity of these solutions to the near surface environment leads to evaporative concentration of salts, creating a potential dryland salinity hazard.

The lowland Simmons Creek Catchment is characterised by comparatively little exposed bedrock and lower angle landforms covered by parna. These landforms and materials are responsible for salt accumulation, large-scale sodicity and development of areas of highly saline groundwater. A bedrock aquitard slowing water movement from the catchment and a positive regional groundwater head beneath the alluvial plain contribute to extremely low hydraulic conductivity in the regolith, and consequently evaporative concentration of salts in the near surface environment is significant. Assuming an entirely atmospheric input, salt accumulation rates and stored salt masses in the Simmons Creek Catchment are also greater in the unsaturated zone than in the groundwater. Interaction of low hydraulic conductivity groundwater with the regolith determines that the highest salt concentrations are found in these shallow aquifers, while in the deeper groundwater and in regolith or shallow groundwater beyond the influence of the hydrologic restrictions concentrations are generally lower.

Rates of salt accumulation are similar between upland and lowland catchments, indicting that salt input is generally balanced by loss through leaching.

Quaternary climatic variation has significantly influenced the modern landscape, with climatic variability and landscape erosional stability and instability largely responsible for the development of the regolith in southeast New South Wales. Landform and regolith evolution with respect to hydrology are the major determinants of salt distribution in the present landscape, and evaporation of salts sourced dominantly from precipitation is the primary concentration mechanism. The majority of the salt mass within the landscape is found in the unsaturated regolith, while greatest salt concentrations are found in groundwater, its depth of accumulation strongly influenced by the dominance of leaching or accumulation conditions in the regolith. With this in mind, the distribution and evolution of parna in the UBCC has implications for many upland catchments in southeastern New South Wales, where unrecognised parna materials may exert significant controls on local hydrology and the potential for development of waterlogging, sodicity and salinity.

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