THE UNIVERSITY OF ADELAIDE

The influence of soil genesis, type and composition on constraints to plant growth in salt-affected soils in Upper South East South Australia

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ABSTRACT

This thesis documents the physicochemical, mineralogical, geochemical and morphological characteristics of two major soil types present on the interdunal Avenue Plain in the Upper South East of South Australia. Their evolution in the landscape is hypothesised. The district has historically been affected by dryland salinity and seasonal flooding; artificial drainage has been adopted in some areas to ameliorate these constraints. The study was instigated in collaboration with members of the Keilira Farm Management Group (KFMG) in response to a perceived decline in pasture growth since the establishment of the Fairview Drain in the Keilira District in 1997.

A preliminary study was conducted on three properties at Keilira; two included drains (South and Central sites) and one was un-drained (North), with the aim of investigating the effects of artificial drainage on soil physicochemical condition. Annual rainfall and standing water levels (SWL) in a series of observation wells were assessed. Results showed that groundwater levels have fallen both with a decline in annual rainfall and the implementation of artificial drainage. The lowering of SWL has facilitated the leaching of salts, often resulting in the expression of sodicity. Comparison with 1950 (pre-drainage) data confirmed that a change in soil physicochemical condition has occurred at both drained and un-drained sites. Poor plant growth was prevalent when the soils were both chemically hostile and structurally unstable. Soil type and mineralogy were found to vary both across and within study sites; smectite-dominant soils located at the un-drained North site exhibited the most hostile chemical conditions for plant growth.

Subsequent studies at the South site used geophysical tools and soil survey to determine the extent of soil physicochemical variability, whereas mineralogical investigations were performed to identify their cause. Data from the geophysical surveys were used to locate the position for a representative soil trench. Soil samples were collected both across the survey area and within the trench. X-ray Diffraction, X-ray Fluorescence and Transmission Electron Microscopy analyses were conducted both on whole soil samples and the separated clay-size fraction. Petrographic analysis of indurated carbonates was conducted using thin-sections. Carbon and oxygen isotopic analysis was performed to determine the type and origin of the carbonates present.

Two distinct soil types were detected at the site, a Chromosol overlying indurated carbonate that supported good pasture growth and species diversity, and a deep saline-sodic Vertosol that supported only poor pasture growth. The electromagnetic induction survey revealed discrete conductive zones that most likely relate to the depth of the groundwater capillary fringe and presence of clay-rich horizons. Ground Penetrating Radar detected the isolated patches of deep, extremely saline and strongly sodic Vertosols, in addition to numerous indurated carbonate horizons.

Results confirmed that the variability of soil types and carbonate morphology is related to position in the landscape and historic oscillations in ground and surface water levels. Chromosols are predominately found on the eastern side of the Avenue Plain and within the shorelines of lunettes where calcareous lacustrine sediments were periodically exposed and modified, resulting in the development of highly indurated palustrine limestones. These soils are dominated by illite and kaolinite clay minerals that are

stratified above the palustrine barrier; they respond well to artificial drainage and chemical amelioration.

The Vertosols are located predominately on the western side of the interdunal plain in the lowest parts of the landscape, such as in the basins of lunettes and throughout natural drainage lines. These soil types are particularly prone to the development of high pH, extreme salinity and strong sodicity and can be difficult to ameliorate. One particularly degraded Vertosol was dominated in surface horizons by the Mg-rich clay mineral saponite, whereas other horizons contained montmorillonite, sepiolite and palygorskite, in addition to Mg-rich calcite and ankerite.

In addition to this work the KFMG instigated on-farm research (OFR) to investigate amelioration strategies. Extension activities were conducted to improve farmer knowledge and facilitate management change. A survey conducted with the three farmers intimately involved in the project confirmed that the combination of off-site research, OFR and regular extension activities improved their knowledge of dryland salinity, sodicity and soil variability on their farms. Management practices have been affected as a result.

It is concluded that the decline in pasture growth observed is due primarily to the sporadic presence of Vertosols that are extremely saline, strongly sodic and very strongly alkaline. Poor plant growth may also be observed on Chromosols when sodic.

STATEMENT OF DECLARATION

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Melissa Fraser and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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THESIS STRUCTURE

This PhD project came to fruition in 2005 when a group of farmers from South Australia's Upper South East approached the University of Adelaide to help them investigate a problem they observed on their farms. I was looking for a new challenge and came on-board, intrigued by the nature of their concerns and excited about working with a group of growers and the prospect of incorporating an extension component into my research project. This thesis documents the studies and activities that were conducted to help the Keilira farmers understand the cause of declining plant growth across their farms and the factors that lead to its development. Each Chapter contained herein has been written as an independent document in a format appropriate for publication in scientific journals; some degree of repetition therefore occurs since journal articles must be self-contained.

Chapter 1 introduces the problems encountered by the farmers and gives an overview of the environmental setting for the study. As this environment was/is affected by dryland salinity, a review of literature follows focusing on saline and sodic soils. As the degree of structural degradation in sodic soils is affected by clay mineralogy, a review of soil clay minerals is also included.

Chapter 2 investigates the flux of groundwater levels throughout the study area, with particular reference to the effect of deep artificial drains. Three core study sites were selected and the current soil condition is compared to historic data for two key soil types identified.

Chapter 3 explains how geophysical equipment was used to identify the location for a large study trench that was subsequently excavated. Physicochemical data collected within the trench and from other sampling points allowed inferences to be made about the features that were detected in the geophysical surveys.

Chapter 4 investigates the study trench in more detail, with particular reference to the clay mineral and carbonate types and variability present. Based on these data, hypotheses explaining the evolution of the landscape and the soil types are formulated.

Chapter 5 is an evaluation of the project and its outcomes, including how the knowledge and skills of the participating growers has changed since the projects inception.

Chapter 6 summarises and discusses the findings from this thesis and makes recommendations for future research arising from the work presented.