



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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A thesis submitted for the degree of
Doctorate of Philosophy

Faculty of Sciences, School of Earth and Environmental Science

May 2011

TABLE OF CONTENTS

TABLE OF CONTENTS	II
ABSTRACT.....	VI
STATEMENT OF DECLARATION	VI
ACKNOWLEDGEMENTS.....	X
THESIS STRUCTURE	XII
CHAPTER 1	1
INTRODUCTION.....	1
1.1 ENVIRONMENTAL SETTING	5
1.2 SALT-AFFECTED SOILS IN AUSTRALIA	8
1.3 SOIL SALINITY	9
1.3.1 Salinity in the USE	12
1.3.2 Effects of salts on plants and soils	13
1.4 SODICITY.....	15
1.4.1 Exchangeable Sodium Percentage.....	16
1.4.2 The deterioration of soil structure by dispersion	17
1.4.3 The nature and content of organic matter and clay dispersion	19
1.4.4 Soil pH and clay dispersion	20
1.4.5 Mineralogical composition and dispersion.....	21
1.4.6 Dominance of calcium vs. magnesium	22
1.4.7 Soil biology.....	22
1.4.8 Mechanical disturbance and clay dispersion.....	23
1.4.9 Sodicity and clay dispersion, effects on soil permeability and water holding characteristics.....	23
1.5 SOIL MINERALOGY.....	25
1.5.1 Kaolinite	26
1.5.2 Illite	27
1.5.3 Smectite.....	28
1.5.4 Non Phyllosilicate minerals.....	31
1.6 CONCLUSION	32
1.7 HYPOTHESES.....	33
1.8 REFERENCES	34

CHAPTER 2	39
ARTIFICIAL DRAINAGE AFFECTS THE PHYSICOCHEMICAL PROPERTIES OF SALT-AFFECTED HEAVY CLAY SOILS IN THE UPPER SOUTH EAST OF SOUTH AUSTRALIA.....	
2.1 INTRODUCTION	39
2.2 ENVIRONMENTAL SETTING OF THE STUDY.....	42
2.3 METHODS.....	45
2.3.1 Historic Groundwater Trends	46
2.3.2 Trench Location and Sampling.....	46
2.3.3 Soil Chemical Analyses.....	47
2.4 RESULTS.....	49
2.4.1 South Study Site.....	49
2.4.1.1 <i>Groundwater Trends</i>	50
2.4.1.2 <i>Soil Chemistry</i>	51
2.4.2 Central Study Site	52
2.4.2.1 <i>Groundwater Trends</i>	53
2.4.2.2 <i>Soil Chemistry</i>	55
2.4.3 North Study Site.....	56
2.4.3.1 <i>Groundwater Trends</i>	56
2.4.3.2 <i>Soil Chemistry</i>	57
2.4.4 Clay Mineralogy of the Soils	58
2.5 DISCUSSION	60
2.5.1 Rainfall, artificial drainage and groundwater trends.....	60
2.5.2 Interpretation of soil properties.....	62
2.5.2.1 <i>Smectite-rich Soils</i>	62
2.5.2.2 <i>Illite-Kaolinite- rich soils</i>	66
2.6 CONCLUSION	68
2.7 REFERENCE LIST.....	70
CHAPTER 3	72
COMBINING GEOPHYSICAL TOOLS, SOIL SURVEY AND SOIL CHEMISTRY TO INVESTIGATE THE CAUSE OF SPATIAL VARIABILITY OF SOILS IN THE UPPER SOUTH EAST OF SA	
3.1 INTRODUCTION	72
3.2 METHODS.....	74
3.2.1 Study Site	75
3.2.2 Geophysical Surveys	75
3.2.3 Preliminary Soil Sampling	77

3.2.4 Soil Chemical Analysis.....	77
3.2.5 Trench Location	78
3.2.6 Trench Soil Sampling and Chemical Analysis	79
3.3 RESULTS.....	80
3.3.1 EMI Survey.....	80
3.3.2 GPR Survey.....	81
3.3.3 Preliminary Soil Survey	84
3.3.4 Trench Results	86
3.4 DISCUSSION.....	89
3.4.1 Key Profiles	90
3.4.2 Relationships between soil profile properties and geophysical features.....	92
3.4.3 Relationship between EMI and GPR patterns	95
3.5 CONCLUSION	98
3.6 REFERENCE LIST.....	99
 CHAPTER 4	 101
 GENESIS AND DISTRIBUTION OF CLAY MINERALS AND CARBONATES IN LACUSTRINE AND PALUSTRINE SEDIMENTS OF UPPER SOUTH EAST SA.....	 101
4.1 INTRODUCTION	101
4.1.1 Study setting.....	102
4.1.2 Types of continental carbonates and their identification	104
4.1.3 Previous studies of soils in the region	109
4.2 METHODS.....	111
4.3 RESULTS.....	113
4.3.1 XRD patterns of the Powder Bulk Samples.....	113
4.3.2 Elemental analysis	117
4.3.3 XRD patterns and TEM of the <2 µm fraction.....	119
4.3.4 Petrographic examination	124
4.3.5 Isotopic analysis.....	128
4.4 DISCUSSION.....	129
4.4.1 Genesis and types of clay minerals.....	129
4.4.2 Genesis of lacustrine, palustrine and calcrete carbonates on the Avenue Plain.....	135
4.4.2.1 <i>Palustrine limestones</i>	136
4.4.2.2 <i>Lacustrine marl and clay</i>	138
4.4.2.3 <i>Groundwater calcretes / silcretes</i>	139
4.4.2.4 <i>Pedogenic calcretes</i>	143
4.4.3 Development of soil profiles.....	144

4.5 CONCLUSION	149
4.6 REFERENCE LIST	151
 CHAPTER 5	 155
 ON-FARM RESEARCH IMPROVES FARMER KNOWLEDGE AND FACILITATES CHANGE	 155
5.1 INTRODUCTION	155
5.2 METHODS AND ACTIVITIES.....	157
5.3 RESULTS AND DISCUSSION	159
5.3.1 Knowledge of salinity and sodicity	159
5.3.2 Management practices, production and sustainability	162
5.3.3 On-farm research and extension methods.....	166
5.3.4 Community perception and the drainage schemes.....	169
5.4 CONCLUSIONS	170
5.5 REFERENCES	171
 CHAPTER 6	 172
 GENERAL DISCUSSION AND CONCLUSIONS.....	 172
6.1 INTRODUCTION	172
6.2 SUMMARY OF RESEARCH AND CONTRIBUTION TO KNOWLEDGE	173
6.3 GENERAL DISCUSSION	185
6.3.1 Illite- and Kaolinite-rich soils.....	185
6.3.2 Smectite-rich soils.....	188
6.4 LIMITATIONS OF THE STUDY AND RECOMMENDATIONS FOR FUTURE RESEARCH	192
6.5 CONCLUSIONS	197
6.6 REFERENCES	199
 APPENDIX 1	 201
 APPENDIX 2	 204
 APPENDIX 3	 205

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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Date

ACKNOWLEDGEMENTS

This research was conducted under the supervision of Associate Professor David Chittleborough, Dr Jock Churchman and Dr Pichu Rengasamy from the University of Adelaide (U of A). I was also aided by the assistance and inspiration provided by Richard Merry (CSIRO), Adrian Beech (CSIRO), Mark Raven (CSIRO), Peter Self (CSIRO) and Colin Rivers (U of A). Editorial assistance was provided by Margaret Cargill (U of A) whose contribution was invaluable. The interpretation of petrography was aided by Pontifex and Associates and geophysical data by Ecophyte Technologies. My sincere and wholehearted thanks go to all of these people for their patience, guidance and encouragement throughout my candidature.

This research would not have been possible without the help and input from the three farmers primarily involved in this project. Their donation of time, land and resources was crucial to the success of this thesis and I thank them for their enthusiasm, persistence and willingness to participate. I hope that this research will contribute to improving the sustainability and viability of their farming systems for years to come.

Financial assistance for this research was provided by the University of Adelaide, School of Earth and Environmental Science, the CRC for Plant Based Management of Dryland Salinity, the Future Farm Industries CRC, the Keilira Farm Management Group and South East Natural Resources Management Board. I am very grateful for the personal and professional development opportunities that were provided by both the University and the CRC and would particularly like to thank Daryll Richardson (CRC) and Dr Ron Smernik (U of A) for their continued enthusiasm for enhancing the PhD experience.

I would also like to thank my family and friends for their support and encouragement during my 4 years of full-time study and 2 years part-time. Thanks especially go to Jock, who became a dear friend that I have steadfastly been able to rely upon. Richard Merry also provided core background knowledge and encouragement and has inspired me to become a better scientist. I would also like to acknowledge my past university lecturers, Ann McNeill who gave me the courage to embark on this journey, and Cameron Grant whose healthy level of criticism encouraged me to do better. A special mention must also go to my fellow post-grad students who made the journey a little less daunting and the friends that always had an open office door to listen to my gripes: Debbie Miller, Thea Williams, David Summers, Kate Langdon and Lisa Le in particular.

Finally I would like to thank my partner, Sean Chalmers, for being brave enough to take on a relationship with someone mid-way through a PhD. I look forward to embarking on our newly married life together and to building our home and life in the NT.

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.