THE EFFECTS OF SALINITY AND SODICITY ON SOIL ORGANIC CARBON STOCKS AND FLUXES

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DECLARATION OF ORIGINALITY

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of the author's knowledge, it contains no material previously published or written by another person, except where due reference is made in the text.

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ABSTRACT

Soil is the world's largest terrestrial carbon (C) sink, and is estimated to contain approximately 1600 Pg of carbon to a depth of one metre. The distribution of soil organic C (SOC) largely follows gradients similar to biomass accumulation, increasing with increasing precipitation and decreasing temperature. As a result, SOC levels are a function of inputs, dominated by plant litter contributions and rhizodeposition, and losses such as leaching, erosion and heterotrophic respiration. Therefore, changes in biomass inputs, or organic matter accumulation, will most likely also alter these levels in soils. Although the soil microbial biomass (SMB) only comprises 1-5% of soil organic matter (SOM), it is critical in organic matter decomposition and can provide an early indicator of SOM dynamics as a whole due to its faster turnover time, and hence, can be used to determine soil C dynamics under changing environmental conditions.

Approximately 932 million ha of land worldwide are degraded due to salinity and sodicity, usually coinciding with land available for agriculture, with salinity affecting 23% of arable land while saline-sodic soils affect a further 10%. Soils affected by salinity, that is, those soils high in soluble salts, are characterised by rising watertables and waterlogging of lower-lying areas in the landscape. Sodic soils are high in exchangeable sodium, and slake and disperse upon wetting to form massive hardsetting structures. Upon drying, sodic soils suffer from poor soil-water relations largely related to decreased permeability, low infiltration capacity and the formation of surface crusts. In these degraded areas, SOC levels are likely to be affected by declining vegetation health and hence, decreasing biomass inputs and concomitant lower levels of organic matter accumulation. Moreover, potential SOC losses can also be affected from dispersed aggregates due to sodicity and solubilisation of SOM due to salinity. However, few studies are available that unambiguously demonstrate the effect of increasing salinity and sodicity on C dynamics. This thesis describes a range of laboratory and field investigations on the effects of salinity and sodicity on SOC dynamics.

In this research, the effects of a range of salinity and sodicity levels on C dynamics were determined by subjecting a vegetated soil from Bevendale, New South Wales (NSW) to one of six treatments. A low, mid or high salinity solution (EC 0.5, 10 or 30 dS/m) combined with a low or high sodicity solution (SAR 1 or 30) in a factorial design was leached through a non-degraded soil in a controlled environment. Soil respiration and the SMB were measured over a 12-week experimental period. The greatest increases in SMB occurred in treatments of high-salinity high-sodicity, and high-salinity low-sodicity. This was attributed to solubilisation of SOM which provided additional substrate for decomposition for the microbial population. Thus, as salinity and sodicity increase in the field, soil C is likely to be rapidly lost as a result of increased mineralisation.

Gypsum is the most commonly-used ameliorant in the rehabilitation of sodic and saline-sodic soils affected by adverse soil environmental conditions. When soils were sampled from two sodic profiles in salt-scalded areas at Bevendale and Young, SMB levels and soil respiration rates measured in the laboratory were found to be low in the sodic soil compared to normal non-degraded soils. When the sodic soils were treated with gypsum, there was no change in the SMB and respiration rates. The low levels of SMB and respiration rates were due to low SOC levels as a result of little or no C input into the soils of these highly degraded landscapes, as the high salinity and high sodicity levels have resulted in vegetation death. However, following the addition of organic material to the scalded soils, in the form of coarsely-ground kangaroo grass, SMB levels and respiration rates increased to levels greater than those found in the non-degraded soil. The addition of gypsum (with organic material) gave no additional increases in the SMB.

The level of SOC stocks in salt-scalded, vegetated and revegetated profiles was also determined, so that the amount of SOC lost due to salinisation and sodication, and the increase in SOC following revegetation relative to the amount of SOC in a vegetated profile could be ascertained. Results showed up to three times less SOC in salt-scalded profiles compared to vegetated profiles under native pasture, while revegetation of formerly scalded areas with introduced pasture displayed SOC levels comparable to those under native pasture to a depth of 30 cm. However, SOC stocks can be underestimated in saline and sodic landscapes by setting the lower boundary at 30 cm due to the presence of waterlogging, which commonly occurs at a depth greater than 30 cm in saline and sodic landscapes as a result of the presence of high or perched watertables. These results indicate that successful revegetation of scalded areas has the potential to accumulate SOC stocks similar to those found prior to degradation.

The experimental results from this project indicate that in salt-affected landscapes, initial increases in salinity and sodicity result in rapid C mineralisation. Biomass inputs also decrease due to declining vegetation health, followed by further losses as a result of leaching and erosion. The remaining native SOM is then mineralised, until very low SOC stocks remain. However, the C sequestration potential in these degraded areas is high, particularly if rehabilitation efforts are successful in reducing salinity and sodicity. Soil ecosystem functions can then be restored if organic material is available as C stock and for decomposition in the form of either added organic material or inputs from vegetation when these salt-affected landscapes are revegetated.

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LIST OF ACRONYMS AND ABBREVIATIONS

AGO	Australian Greenhouse Office
ANOVA	Analysis of variance
CEC	Cation exchange capacity
CFC	Critical flocculation concentration
C_{mic}:C_{org}	Microbial quotient
DOC	Dissolved organic carbon
EC	Electrical conductivity
ESP	Exchangeable sodium percentage
FAO	Food and Agriculture Organisation
IRGA	Infra-red gas analyser
LSD	Least significant difference
NPP	Net primary productivity
NSW	New South Wales
P_{CO2}	Partial pressure of CO_2
POC	Particulate organic carbon
POM	Particulate organic matter
qCO_2	Specific respiration rate
REML	Residual maximum likelihood
SAR	Sodium adsorption ratio
SED	Standard error of difference
SIC	Soil inorganic carbon
SMB	Soil microbial biomass
SOC	Soil organic carbon
SOM	Soil organic matter
UN	United Nations
WA	Western Australia