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Carbon dynamics of sodic and saline soils following gypsum and organic material additions: A laboratory incubation

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ABSTRACT

Carbon fluxes in sodic and saline soils were investigated by measuring the soil microbial biomass (SMB) and soil respiration rates under controlled conditions over 12 weeks. Gypsum (10 t/ha) and organic material, as kangaroo grass (10 t/ha), were incorporated in an acidic and an alkaline saline–sodic soils. Cumulative soil respiration rates were lowest in the sodic and saline soils without amendment, while the highest rates were found in those soils that had organic material addition. The addition of gypsum decreased the cumulative respiration rates in the 0–5 cm layer compared to the addition of organic material and the addition of organic material and gypsum. Similarly, the SMB was lowest in the sodic and saline soils without amendment and highest in the soils which had organic material addition, while the effects of gypsum addition were not significant. The low levels of respiration and SMB were attributed to the low soil organic carbon (SOC) levels that result from little or no C input into the soils of these highly degraded landscapes as the high salinity and high sodicity levels have resulted in scarcity or absence of vegetation. Following the addition of organic material to the sodic and saline soils, SMB levels and respiration rates increased despite adverse soil environmental conditions. This suggests that a dormant population of salt-tolerant SMB is present in these soils, which has become adapted to such environmental conditions over time and multiplies rapidly when substrate is available.

1. Introduction

Increasing soil salinity, soils high in soluble salts, and sodicity, soils high in exchangeable sodium, are serious land degradation issues worldwide, and are predicted to increase in importance in the future. In Australia, a soil is considered to be saline where the EC of a saturated paste extract (EC_e) ≥ 4 dS/m, and sodic where the exchangeable sodium percentage (ESP) ≥ 6 (Isbell, 1996). Extensive research has been undertaken on the physicochemical properties of saline and sodic soils and their amelioration, particularly with regard to soil structure and vegetation health (e.g. Bramley et al., 2003; Gardner, 2004; Valzano et al., 2001). However, the effects of salinity and sodicity on C dynamics, with respect to C accumulation or losses from soils, are not as well documented or understood. The rate of C accumulation or loss is dependent on the balance between the amount of C input and C loss. Carbon input is dependent on plant inputs and biomass accumulation, as soil organic carbon

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(SOC) levels are dominated by deposition from litterfall and roots. Carbon inputs in salt-affected soils are also likely to decrease as vegetation growth declines due to the direct effects of toxic ions and increases in osmotic potential, and indirect effects in the form of declining soil structure.

The addition of organic materials to soil has frequently been used to aid in the rehabilitation of degraded lands (e.g. Muneer and Oades, 1989; Ros et al., 2003). The importance of maintaining high levels of soil organic matter (SOM), and hence, high levels of SOC, has been well established and is discussed below. SOM can improve soil structure and aggregation (Oades, 1988; Tisdall and Oades, 1982), increase hydraulic conductivity (Baldock et al., 1994), and promote higher nutrient levels and greater cation exchange capacity (von Lutzow et al., 2002). Incorporation of organic material, notably in the form of crop residues, has been shown to improve soil aggregation and increase SOC stocks (Lal et al., 1999), while retaining stubble increases SOM and soil faunal activity (Valzano et al., 2001). In sodic or saline–sodic soils, gypsum ($CaSO_4{\cdot}2H_2O$) is the most commonly used ameliorant to maintain soil electrolyte levels for improving soil physical and hydraulic properties (Keren, 1996).

Carbon dioxide evolution as a result of microbial activity depends on the labile C pool, defined as SOC with a turnover time in the order of weeks (Parton et al., 1987). Substrate utilisation and partitioning of organic C are more sensitive to management induced effects due to their faster turnover times compared to the SOC pool as a whole (Dalal, 1998; Sparling, 1992) and thus reflect changes in soil quality earlier than the total SOM. The metabolic quotient (qCO$_2$) is frequently used to determine stress in the microbial population (Anderson and Domsch, 1993), and measures the ratio of respiration to the soil microbial biomass (SMB). It is assumed that the soil microorganisms produce more CO_2–C per unit microbial biomass per unit time as stress increases, and hence, results in an increase in qCO$_2$ (Anderson and Domsch, 1993). Limited studies have been undertaken on the effects of gypsum on C dynamics and microbial biomass changes in sodic and saline soils. One such study by Carter (1986) suggested that the addition of gypsum caused a decrease in microbial activity, but tended to increase the SMB, attributed to changes in the soil chemical environment. However, the findings are far from conclusive. The addition of organic matter in conjunction with gypsum has been successful in

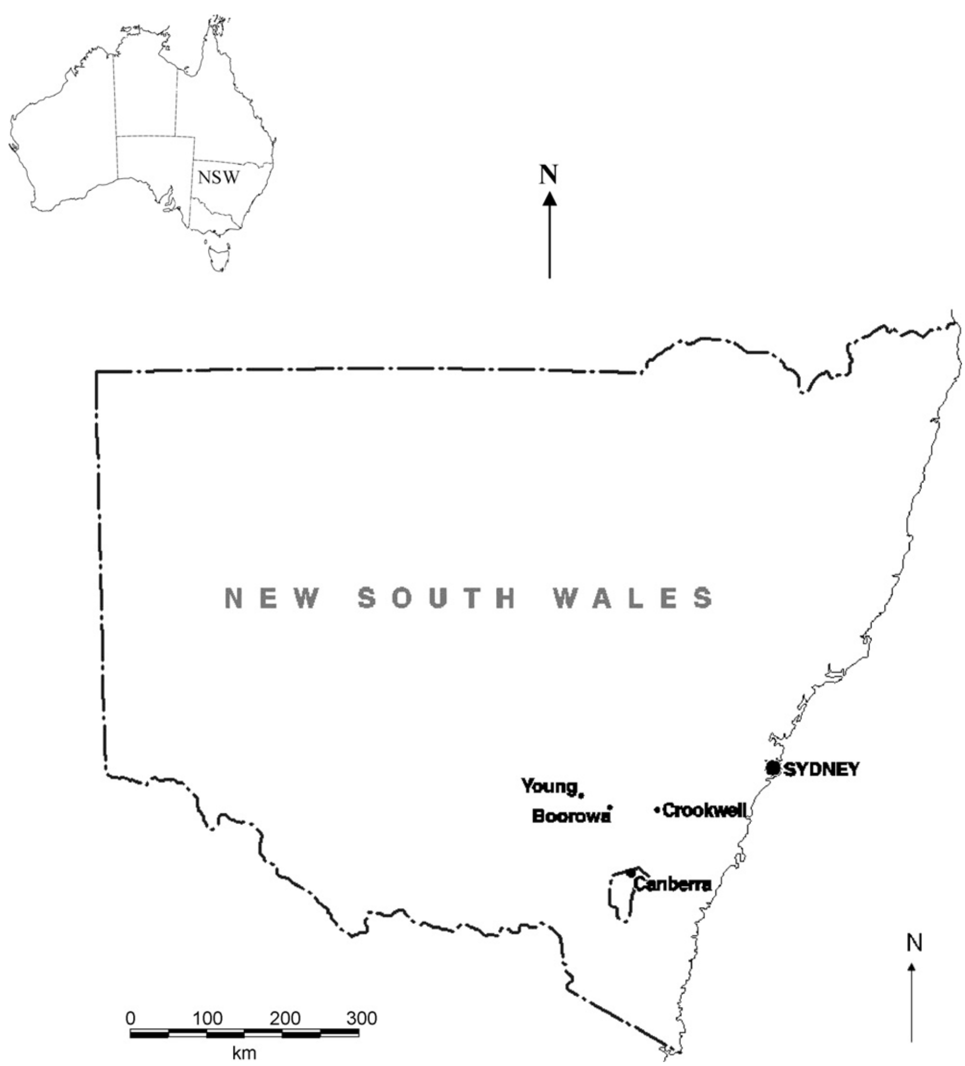

Fig. 1 – Location of the two field sites, "Tarcoola" approximately 40 km southwest of Crookwell, and "Avoca," 20 km northwest of Young.