

# Using salt-amended soils to calculate a rate modifier for salinity in soil carbon models

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## Abstract

In salt-affected soils, soil organic carbon levels are usually low as a result of poor plant growth; additionally, decomposition of soil organic matter may be decreased. Thus, the CO<sub>2</sub> evolution from salt-affected soils is likely to be lower than that from non-saline soils. Carbon models such as Rothamsted Carbon (RothC) that are used to estimate global CO<sub>2</sub> emission do not consider the effect of salinity on CO<sub>2</sub> emission. Given the large extent of salt-affected soils (19 percent of 20.8 billion hectares of arable land on Earth), this may lead to overestimation of CO<sub>2</sub> release. Two laboratory incubation experiments were conducted to assess the effect of soil texture on response of CO<sub>2</sub> release to salinity and to calculate a rate modifier for salinity in soil carbon models and study soil carbon dynamics: a sandy loam (18.8% clay) and a sandy clay loam (22.5% clay) in one experiment and a loamy sand (6.3 % clay) and a clay loam (42 % clay) in another experiment. Sodium chloride (NaCl) was used to develop a range of salinities viz. EC<sub>1:5</sub> 1.0, 2.0, 3.0, 4.0 and 5.0 dS/m. The soils were amended with 2% wheat residues and CO<sub>2</sub> emission was measured over 4 months. Cumulative CO<sub>2</sub>-C/g soil decreased with increased salinity. Cumulative CO<sub>2</sub>-C expressed as percent of the control soil (without salt addition) showed a lower impact of salinity on organic matter decomposition with increasing clay content. A decrease in particulate organic carbon (POC) associated with incubation was less in the higher saline soils whereas total organic carbon, humus-C and charcoal-C did not change over time and were not significantly affected by salinity. A significant exponential relationship was obtained between EC and the salt rate modifier, suggesting that a new salt rate modifier should be incorporated into RothC in order to accurately model CO<sub>2</sub> emissions from salt-affected soils.

## Key Words

Carbon pools, respiration, RothC, salinity.

## Introduction

As the global climate changes, it becomes increasingly important to understand how these changes will affect soils in general but also salt-affected soils which cover large areas in countries with dry climate such as Australia (more than 33% of the total area). Salinity and sodicity are major constraints for successful crop production and have a large impact on soil organic carbon (SOC). Development and effect of soil salinity depends on many edaphic and pedological factors with soil texture being one of the most important. Clay soils have a greater EC buffering capacity; the higher the clay content, the higher the EC at which crop growth is negatively affected (Sumner *et al.* 1998). Soil organic carbon content is a function of C input and C turnover. With lower C inputs in saline soils as a result of poor plant growth, SOC stocks may be lower than in non-saline soils. On the other hand, a lower decomposition rate could lead to similar SOC stocks despite lower inputs. Turnover of SOC is mediated by soil microorganisms such as bacteria and fungi. In salt-affected soils, their activity can be decreased by osmotic stress and/or poor soil structure but little is known about the size and turnover of the different SOC pools in such soils. Several authors have studied the effect of salinity on soil carbon stocks and fluxes in short term incubation experiments. Both increased (Wong *et al.* 2009)) and decreased (Rietz and Haynes 2003) rates of soil organic matter decomposition with increasing salinity have been reported. An enhanced understanding of the implications of salinity on soil carbon dynamics is required to assess the implications of agricultural management on soil carbon stocks. Soil carbon models such as RothC have been successfully validated for non-saline soils (Smith *et al.* 1997) but do not consider the effect of salinity on CO<sub>2</sub> emission, an omission that we hypothesize will lead to inaccurate estimation of point, regional and global CO<sub>2</sub> emissions. In this experiment, different EC levels were imposed in four types of soil to address the following questions. What are the implications of soil salinity on CO<sub>2</sub> emission and SOC dynamics? Is the effect of salinity dependent on soil texture? Using the experimental data, can a rate modifier for salinity be introduced into the RothC model?

## Methods

### Soils

The study included two experiments with saline and non-saline soils from South Australia, each of which was setup as a completely randomised design with three replicates. One experiment was conducted with a sandy loam collected from Kadina and a sandy clay loam from Monarto, and another with loamy sand from Monarto and a clay loam from Kadina (Table 1). This classification is based on the USDA soil classification system.

**Table 1. Physical and chemical properties of the soils.**

Soil texture	EC <sub>1:5</sub> (dS/m)	Clay (%)	Bulk density (Mg/ m <sup>3</sup> )	Water holding capacity (g/ g soil)	Total organic carbon (t/ha)
Loamy sand	0.08	6.3	0.13	1.66	55
Sandy loam	0.46	18.8	0.22	1.47	151
Sandy clay loam	0.82	22.5	0.34	1.41	112
Clay loam	0.30	42.0	0.42	1.28	58

### Treatment of soils

Salinity was developed using NaCl to obtain an EC<sub>1:5</sub> of 1.0, 2.0, 3.0, 4.0 and 5.0 dS/m. The soils remained flocculated at the EC levels used in this experiment. The osmotic potential of the soil water was estimated using the equation:  $O_s = -0.036 EC_{meas} (\theta_{ref} / \theta_{act})$  (Richards, 1954), where  $O_s$  is the soil osmotic potential (MPa) at the actual moisture content ( $\theta_{act}$ , g/g) of the soil and  $EC_{meas}$  is the measured electrical conductivity (dS/m) of the extract at the reference water content ( $\theta_{ref}$ , g/g) of the 1:5, soil/water mixture.

### Incubation and analyses

The air-dry soils were incubated for 14 days at 25 °C at 55 % water holding capacity (WHC) for the sandy loam, 50% WHC for the sandy clay loam, 75 % WHC for the loamy sand and 50%WHC for the clay loam to allow the microbial community to recover and stabilise. This soil water content was achieved by adding the appropriate amounts of saline solutions. Throughout the pre-incubation and the experiment, reverse osmosis water was added to maintain the required water content. After the pre-incubation, 2% mature wheat residue was mixed thoroughly with the soil. Twenty-five g of soil was transferred into PVC cores with a diameter of 3.7 cm and height of 5 cm with a nylon mesh base (0.75 µm, Australian filter specialist) and tapped to give the bulk density shown in Table 1. The cores were transferred into Mason jars fitted with stainless steel septum port to facilitate measuring of headspace gases. Headspace carbon dioxide (CO<sub>2</sub>) concentration was measured throughout the course of the experiments (4 months) by using an infrared gas analyser. Using cumulative CO<sub>2</sub>-C as an estimate, SOC pools (particulate organic carbon, humus-C, charcoal-C) and total organic carbon were determined by mid infrared spectroscopy three times, after 15-20%, 25-35% and 35-45% loss of POC.

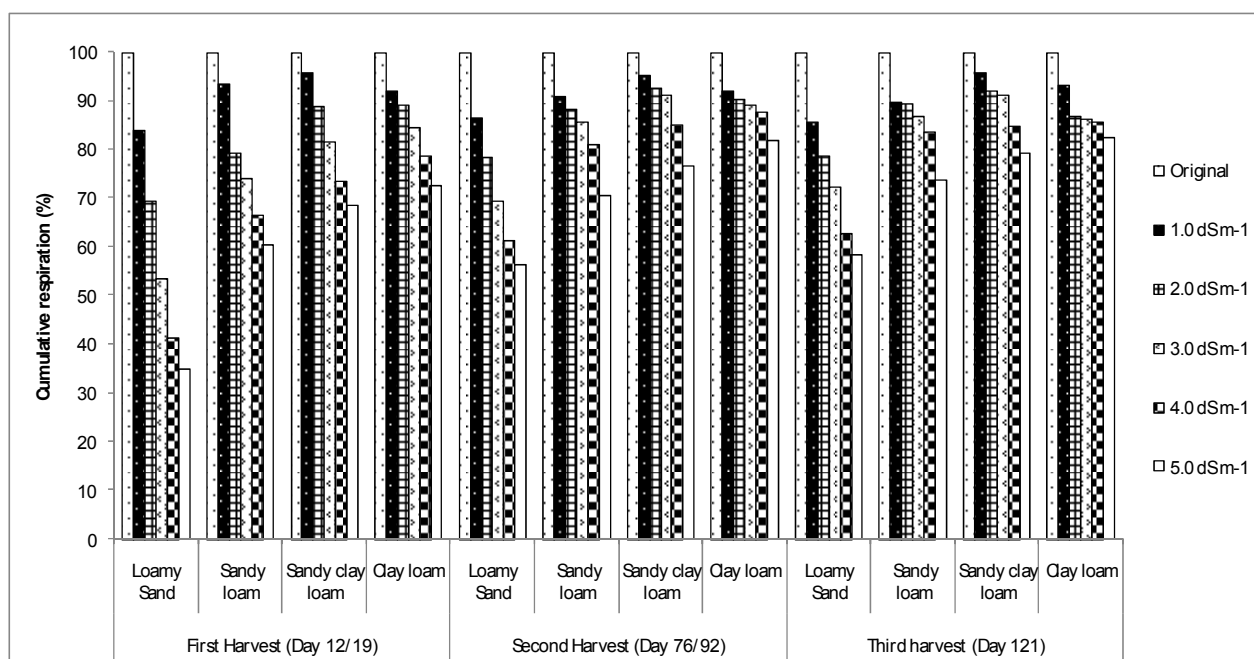
### Modelling of CO<sub>2</sub>-C

The cumulative respiration data was used to develop an equation to modify the rate of decomposition according to salinity and the equation was incorporated into the RothC model (Jenkinson *et al.* 1987, Coleman and Jenkinson 1996).

## Results

### Cumulative respiration

Effects of salinity on decomposition of added wheat straw, and native organic matter, in soil depended on salinity levels and soil texture. Cumulative CO<sub>2</sub>-C decreased with increasing salinity (Figure 1). The average difference in cumulative CO<sub>2</sub>-C evolved between the control (original EC) and the highest EC<sub>1:5</sub> (5.0 dS/m) decreased with time; for example in the sandy loam soil the difference was 20.9% after 12 days, 9.6% after 76 days and 6.1% after 121 days. This may indicate adaptation of the microorganisms to salinity stress over time, although the decreased effect of salinity may also be due to the generally low respiration rates after 13 days. Cumulative respiration was higher in the sandy clay loam than in the sandy loam and higher in the clay loam than in the loamy sand (Figure 1). The decrease in cumulative respiration with increasing salinity (when expressed as EC<sub>1:5</sub>) was higher in the coarse textured soils than in the fine textured soils. Because of the differential water content, the osmotic potential of the soil water at a given EC was lower in the finer textured soils. For example, osmotic potential at EC<sub>1:5</sub> 3.0 dS/m was -5.4 MPa for loamy sand, -4.8 MPa for sandy loam, -3.3 MPa for sandy clay loam and -2.6 MPa for clay loam. The relative decrease in cumulative respiration with increasing osmotic potential was similar in all soils.



**Figure 1. Influence of salinity ( $EC_{1.5}$ ) on cumulative soil respiration (%) over 4 months in soils of varying texture.**

#### *Soil carbon pools*

Due to reduced decomposition rates, a decrease in POC associated with incubation was less in the higher saline soils. Compared to the control soil (without added salt), the POC content at  $EC_{1.5}$  5.0 dS/m was 23% higher in the sandy clay loam at the third harvest. At a given EC level, POC significantly decreased with increasing time because of the loss of C as  $CO_2$  as shown by a negative correlation between cumulative  $CO_2$ -C and POC. Humus-C and charcoal-C did not change significantly with salinity and /or time.

#### *Use of RothC model to simulate $CO_2$ -C in salt-amended soils*

The Roth C was run to calculate the monthly soil  $CO_2$  efflux from known total organic carbon content, clay content and laboratory conditions. The modelled  $CO_2$ -C was lower than measured  $CO_2$ -C of salt-amended soils. In order to match the measured  $CO_2$ -C, equilibrium and the short-term simulations of RothC were run with rate modifiers ranging from 0.2 to 1.0. The rate modifier for each salt-amended soil was calculated by a linear regression between measured minus simulated data and the rate modifier. The intercept of each equation was assumed to be a rate modifier for salinity (Table 2). A significant exponential relationship was obtained between EC and the salt rate modifier, suggesting that a new salt rate modifier should be introduced into RothC to accurately model  $CO_2$  emission from salt-affected soil.

**Table 2. Calculated rate modifiers for salinity at various  $EC_{1.5}$  levels.**

$EC_{1.5}$ (dS/m)	loamy sand	sandy loam	sandy clay loam	clay loam
1.0	0.89	0.85	0.82	0.89
2.0	0.74	0.71	0.75	0.76
3.0	0.60	0.67	0.74	0.61
4.0	0.65	0.63	0.63	0.60
5.0	0.54	0.48	0.53	0.54

#### **Conclusions**

The lower sensitivity of respiration to salinity in the fine textured soils compared to the coarse textured soil is mainly due to the higher water content of the fine textured soils. We conclude that accounting for salinity will provide a more accurate simulation of  $CO_2$  emissions from salt-affected soils but the modified RothC model will need to be evaluated against  $CO_2$  efflux from naturally saline soils. This will help to improve understanding of turnover of soil organic matter as well as providing improved prediction of  $CO_2$  emissions from salt-affected soils. In our experiments, the addition of salt may not have allowed the soil microbes to adapt to salinity as they would in the field where salinity develops more slowly. This may lead to an overestimation of the salinity effect. In order to test this, we are currently conducting an experiment with naturally saline soils.

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