Do texture and organic matter content affect C & N dynamics in soils exposed to dry/wet cycles?

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Introduction

Previous studies have reported both enhanced and reduced C and N cycling when soils of different compositions are exposed to repeated wet/dry cycles. The factors that determine the different responses are poorly understood. The objectives of this study were to determine how soil texture and organic matter content affect short-term C and N dynamics and the production of CO_2 and N_2O over a series drying and rewetting cycles, and then to use CO_2 and N_2O produced at constant moisture contents to calculate production during dry/wet cycles and compare this to actual production.

Materials & methods

Soil samples were collected from six paddocks on each of two soil types with contrasting textures (silt loam & clay loam) to produce an organic matter gradient for each. The soils (bulk density = 1.1 g/cm^3) were incubated aerobically for 92 days in gas tight chambers fitted with rubber septa for gas sampling. The experiment consisted of three phases (Figure 1):

1) Pre-incubation phase (14 days at field capacity [FC, -0.01 MPa])
2) Treatment phase (treatments as described below)
3) Recovery phase (soils returned to FC, 18 days).

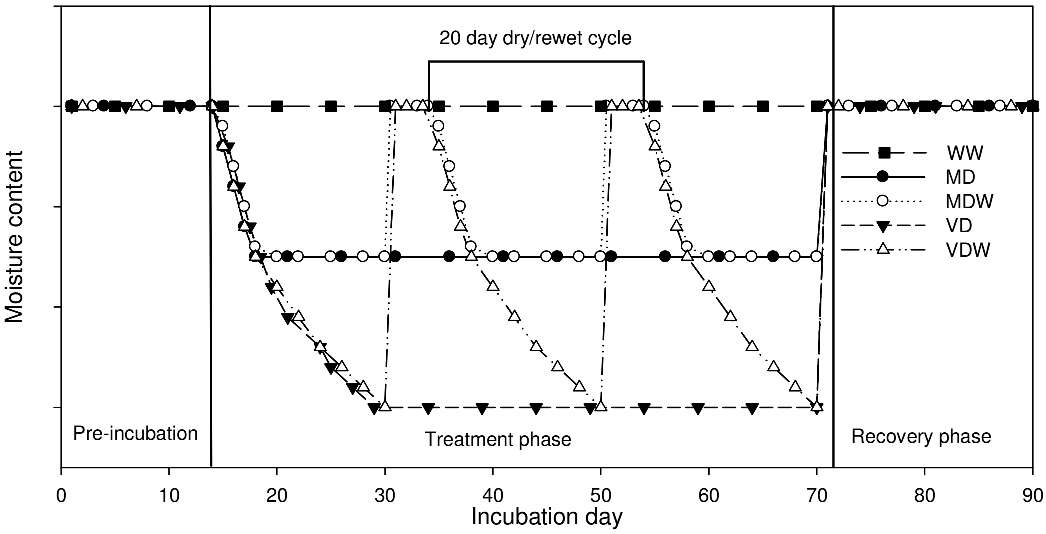


Figure 1. A schematic diagram representing the experimental phases and dry/wet treatments.

Three constant moisture and two dry/wet cycle treatments were imposed during the treatment phase (Table 1).

Table 1. Dry/rewet treatments.

Treatment name	Treatment ID	Moisture Treatment	Rewet treatment
Continuously moist	WW	FC	Maintained at FC
Moderately dry, rewet	MDW	120% WP	+ rewet
Very dry, rewet	VDW	80% WP	+ rewet
Moderately dry	MD	120% WP	- rewet
Very dry	VD	80% WP	- rewet

The dry/wet treatments (MDW and VDW) included three 20-day cycles each consisting of 16-day drying, rapid rewetting and 4 days at FC. Dry treatments (MD and VD) were dried down and incubated for duration of the treatment phase. Drying was achieved using silica gel, allowing continuous measurement of CO_2 (IRGA) and N_2O (GC) during the experiment. At the end of each phase soils were analysed for KCl extractable mineral N (Min N), and cold water (CWEC) and hot water (HWEC) extractable C.

Results and Discussion

Overall, total CO_2 production (cumulative C mineralised), HWEC and CWEC were positively related to the initial organic matter content (mg C/g soil), but this relationship was much more evident in the silt loam soils (Figure 2A, B & C). Progressively less C was mineralised with increasing frequency and intensity of drying (WW>MDW>VDW>MD>VD) in both soil types. There was evidence that, in the silt loam soils, HWEC and CWEC are substrates for the C mineralisation as their concentrations were elevated in the dry treatments at the end of the treatment phase and dropped sharply over the recovery phase, but again this relationship was less evident in clay loam soils (Figure 2D, E & F).

There were large differences in KCl extractable mineral N and N_2O emissions between the two soil types (i.e. textures). In the silt loam soils, mineral N increased with organic matter content and decreased with frequency and intensity of drying, and N_2O emissions were highest in the continuously moist (WW) and most intense dry/rewet (VDW) treatments (Figure 3A-C). In contrast there was a poor relationship between mineral N and organic matter content in the clay loam soils, but N_2O emissions were markedly higher in the dry/wet treatments (MDW, VDW) compared to WW, MD and VD treatments.

The total CO_2 production calculated from the constant moisture data showed a very good, positive linear relationship to CO_2 production measured during dry/wet cycles, with $R^2 = 0.96$ and 0.79 for silt loam and clay loam soils respectively (Figure 4A). All of the measured values fell well above the 1:1 line indicating that predictions based on constant moisture results underestimate the effects of repeated dry/wet cycles.

Much of the error in the calculated CO_2 production data arises from an underestimation of mineralisation when the dry soil is rewetted, especially during the first dry/wet cycle and an over estimation of the rate at which respiration decreases as the soil dries, especially in the first drying phase. There is evidence that the fit improves for subsequent dry/wet cycles (Figure 4C).

The N_2O emission data was inherently more variable than the CO_2 data. The clay loam soils tend to have much higher N_2O emissions than the silt loam soils, probably due to the finer texture of these soils leading to the creation of anoxic sites upon rewetting. The correlation between the calculated and measured N_2O emission data was poor, with actual N_2O emissions being, in some cases, several orders of magnitude higher than the calculated emissions (Figure 4B).

Conclusions

Not surprisingly, our results showed a positive relationship between soluble soil C fractions and total soil organic matter. There was also evidence that soluble soil C fractions were substrates for the C mineralised during dry/wet cycles. However, these relationships were more evident in silt loam soils than clay loam soils. This may be because clay loam soils have a greater affinity for sorption of dissolved organic matter, reducing its availability.

Soil N dynamics were greatly influenced by soil texture, particularly N_2O emissions. Fine-textured clay loam soils have a higher proportion of small pores than coarser textured silt loam soils and hence more anoxic sites, increasing N_2O production. Repeated drying and rewetting cycles, even of only moderate intensity, led to much higher N_2O emissions in these finer textured soils.

In order to use CO_2 production data from soils held at constant moisture contents to accurately predict CO_2 production in soils exposed to dry-rewet cycles, knowledge of the stress history for the soil would be required (e.g. size, duration and frequency of rainfall events, dry rates etc.).
Our results indicate that prediction of N_2O emissions in soils exposed to dry-rewet cycles using emission data from soils held at constant moisture contents would be very inaccurate, primarily due to the inherent variability of N_2O emissions in soils.

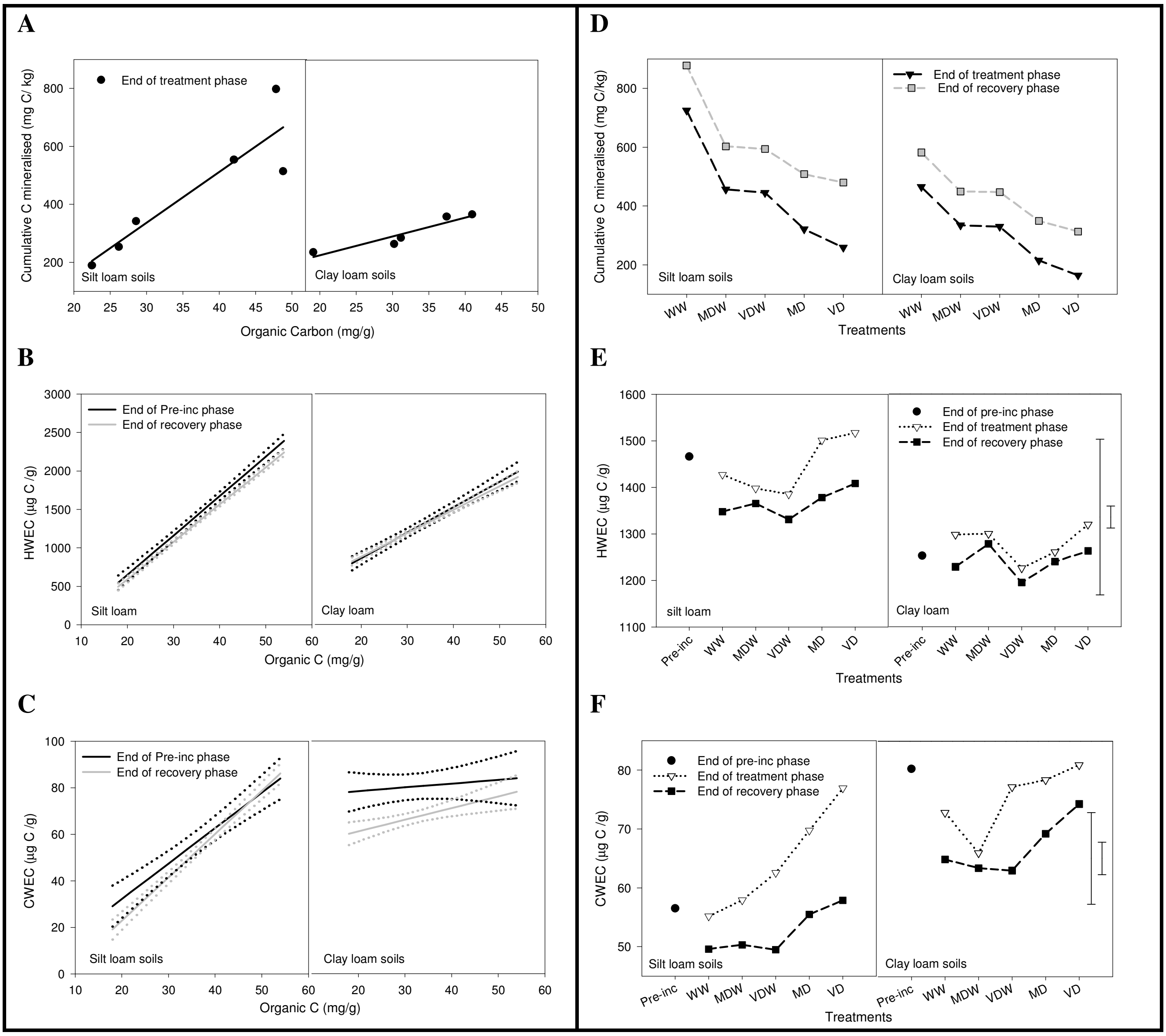
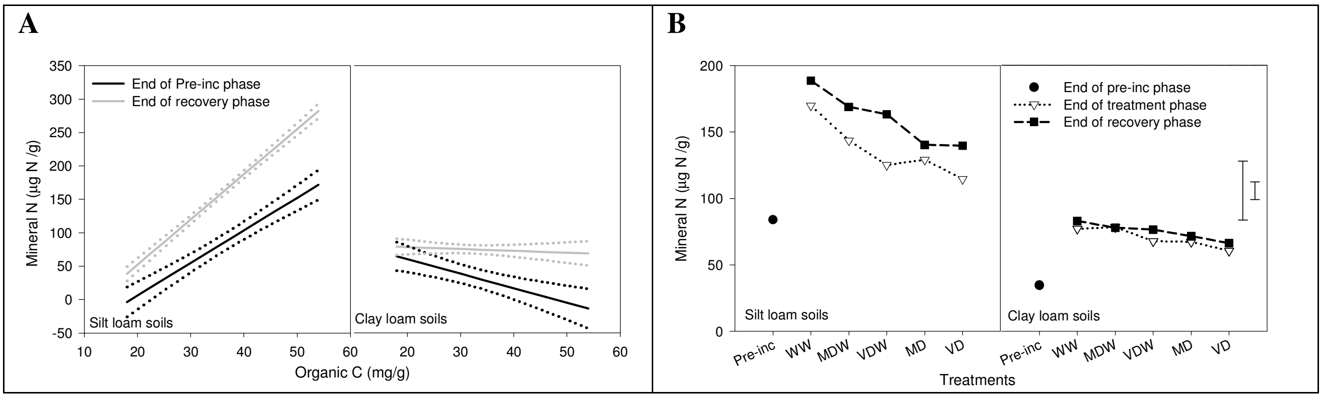


Figure 2. The effect of soil organic matter content on A) C mineralisation and B) CWEC and C) HWEC contents in silt loam and clay loam soils (the dotted lines are 95% Confidence Intervals), and the effect of dry/wet cycles on D) C mineralisation, and E) CWEC and F) HWEC contents in silt loam and clay loam soils (The short bar is the 5% LSD for comparing treatment means within each soil type; the tall bar is for comparing treatment means between soil types).



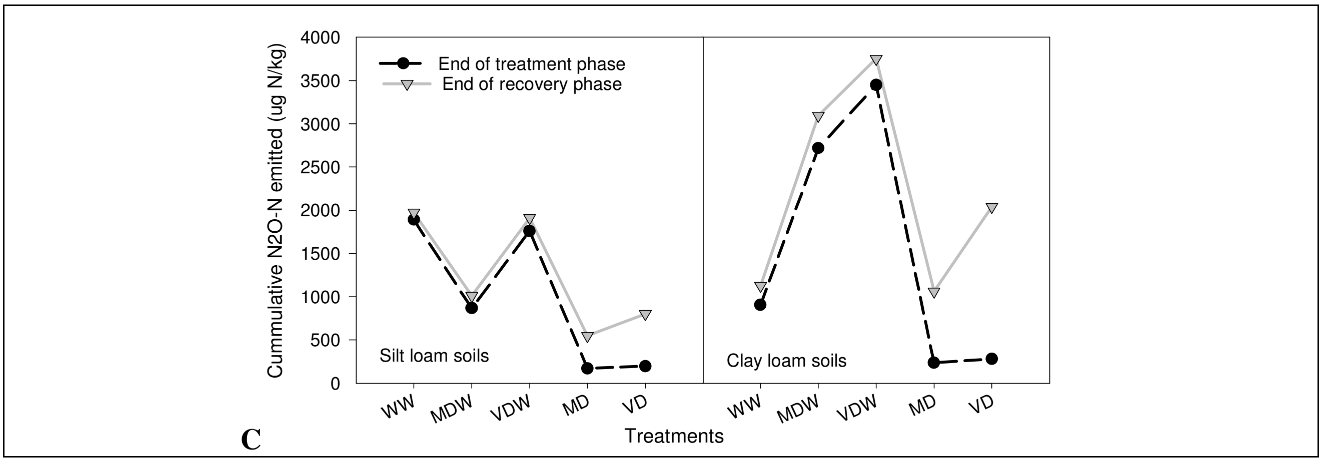


Figure 3. The effect of soil organic matter content on A) mineral N content and dry/wet cycles on B) mineral N content and C) N_2O emissions in silt loam and clay loam soils (the dotted lines are 95% Confidence Intervals and the short bar is the 5% LSD for comparing treatment means within each soil type; the tall bar is for comparing treatment means between soil types).

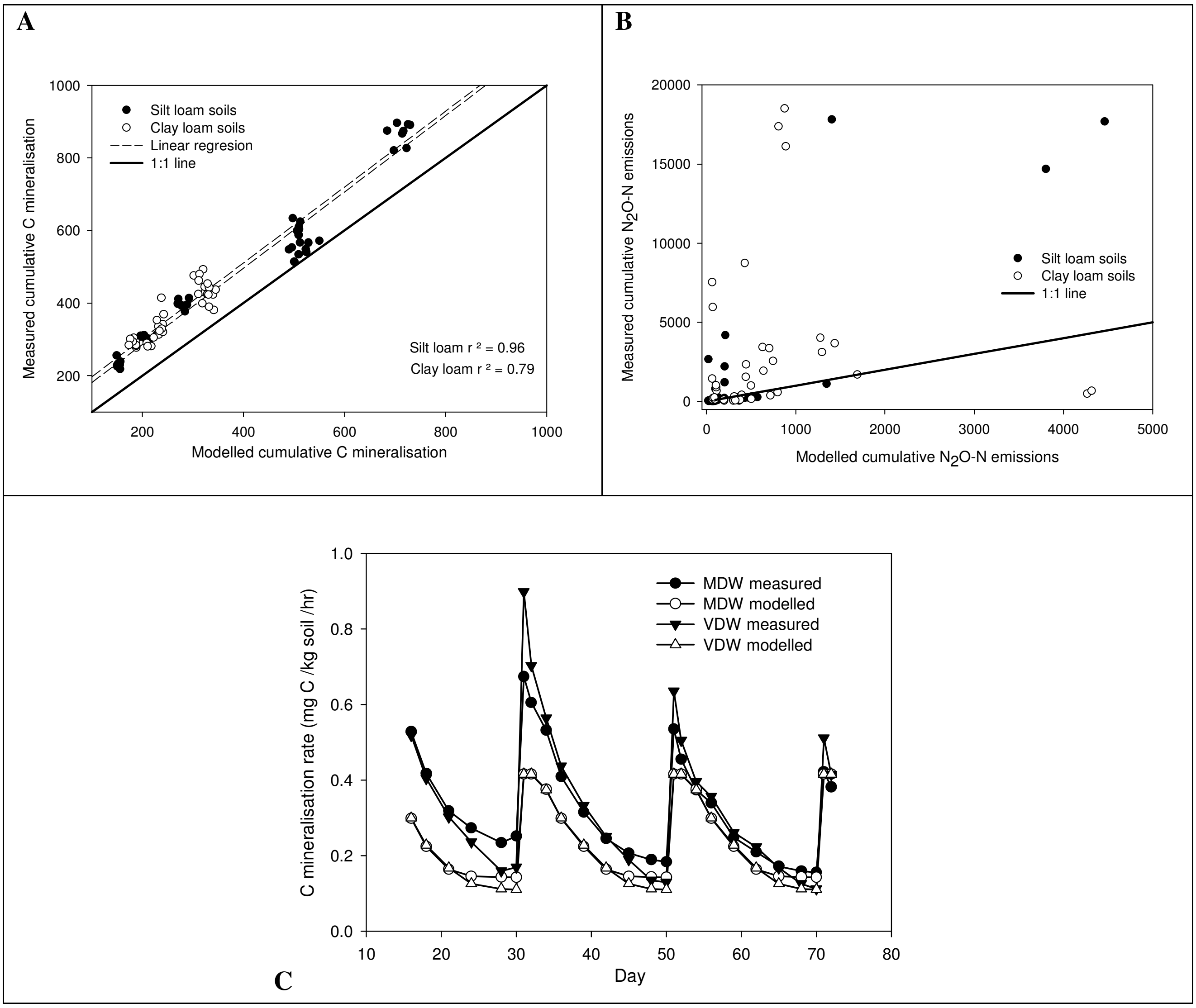


Figure 4. Comparison of calculated and actual A) cumulative C mineralisation B) cumulative N_2O-N emissions and C) mean C mineralisation rates.

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