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EFFECTS OF LAND USE AND SOIL TYPE ON CARBON AND NITROGEN MINERALISATION

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Abstract

Soil organic matter is an important source of plant-available nutrients, particularly nitrogen. In this study, we evaluated (1) effects of land use and soil type on total and mineralisable organic matter, and (2) the efficacy of hot water extractable organic nitrogen as a predictor of mineralisable nitrogen in Waikato soils. Soils were collected at two depths (0–10, 20–30 cm) at 15 sites in the Waikato on either Allophanic (8 sites) or Gley (7 sites) soils. At each site, samples were taken under both long-term pasture and in adjacent maize paddocks, and were immediately sieved (<4 mm). After adjusting soil moisture potential to -10 kPa, they were incubated at 25ºC for 14 weeks to measure carbon and nitrogen mineralisation. Hot water extractable carbon and nitrogen, and total carbon and total nitrogen were determined using air-dried soil samples. Total organic matter ranged from very low (5 g C kg^{-1}) to very high (150 g C kg^{-1}). Organic matter content was greater in surface soils but did not differ ($P > 0.05$) between soil types or between the two land uses. Overall, mineralised carbon and nitrogen were influenced by land use (pasture > maize in topsoil) but not soil type. There was a strong relationship ($R^2 = 0.89$; n = 60) between hot water extractable organic N and mineralisable nitrogen, supporting the use of the hot water extractable organic nitrogen test for routine assessment of mineralisable nitrogen.

Introduction

Soils play an important role in global carbon (C) and nitrogen (N) cycles. Soil organic matter (SOM) is a major reservoir of nutrients, including nitrogen, and has a strong influence on soil fertility and productivity (Andrews, Karlen, et al., 2004, Jimenez, Lorenz, et al., 2011). SOM can be either a sink or a source of carbon to the atmosphere and has a potential to mitigate the impacts on climate change (Sardans and Penuelas, 2012). Land use and management practices are considered important drivers of the quantity and quality of organic matter in soils (Qin, Dunn, et al., 2016).

The specific aims of this study were (1) to evaluate effects of land use and soil type on total and mineralised organic matter; (2) to investigate the efficacy of hot water extractable organic nitrogen as a predictor of mineralisable nitrogen in Waikato soils.

Material and methods

Soil sampling and preparation

Soil samples were collected (0–10 and 20–30 cm depths) in May 2019 at 15 sites in the Waikato region on either Allophanic (8 sites; Horotiu, Otorohanga, Pairere series) or Gley (7 sites; Te Kowhai, Mangapiko and Waitoa series) soils. At each site, samples were taken under long-term pasture and in adjacent maize paddocks. The soils represented a wide range of textures (clay content: 16–65% in the surface layer). In the laboratory, the field-moist soils were passed through a 4 mm sieve. Measurements of water holding capacity at -10 kPa indicated that the soils were close to field capacity when they were collected. The samples were split in two parts. One part was air-dried for determination of total and hot water extractable C and N, and the

other was kept field moist (in a cold room at ~4ºC) before use in the incubation study to measure C and N mineralisation.

Laboratory measurements

Total C and N were measured by Dumas combustion using a LECO TruMac C/N analyser (LECO TruMac, Leco Corporation, St. Joseph, MI, USA). Hot water extractable N and C were determined as described by Curtin, Wright, et al. (2006) and Ghani, Dexter, et al. (2003), with slight modifications. Soil samples (4 g) were shaken for 30 min in 40 mL of deionized water before being placed in a water bath at 80°C for 16 h. The soil-water suspensions were then centrifuged at 3500 rpm for 20 min and the supernatants filtered through pre-leached Munktell 393 filter papers. Organic C in the extracts was determined by a total organic carbon analyzer (Shimadzu TOC-$V_{CSH,}$ Shimadzu Corp, Japan).

Total nitrogen in the extracts was determined after persulphate digestion (Cabrera and Beare, 1993) to oxidise organic N to NO_3^-, which was measured on a Lachat Quikchem Flow Injection Analysis System (Lachat FIA). Dissolved organic N was calculated by subtracting mineral N (NH_4^+ and NO_3^-; determined using the Lachat FIA) from total N.

Carbon mineralisation was measured by incubating soils at field capacity (25 g oven-dry soil equivalent) in 1 L air-tight jars (with a rubber septum on the lid) for 14 weeks at 25°C. A gas-tight Hamilton syringe with a non-coring needle was used to collect headspace air periodically (total 17 samplings during the 14-week incubation). A 20 ml sample of well-mixed headspace air from each jar was withdrawn for CO_2 determination using an infra-red gas analyser (LI-COR, Lincoln, Nebraska). The jars were opened and flushed with fresh air to return CO_2 concentrations to ambient levels after each sampling. The water content of incubated soils was adjusted to field capacity weekly to offset evaporation losses.

Nitrogen mineralisation was determined using an aerobic incubation similar to that described for C mineralisation (soil samples were adjusted to field capacity and incubated at 25°C for 14 weeks). Mineral N (NH_4^+ and NO_3^-) was extracted in 2 *M* KCl and determined using an automated colorimeter. Mineralised N was estimated by subtracting initial soil mineral N from that measured after the 14 week incubation.

Data analysis

Effects of soil type, land use and sampling depth on total C and N, C and N mineralisation and hot water extractable C and N were evaluated using ANOVA with least significant differences calculated at $p \leq 0.05$ using "aov" command in R. Plots of analyzed variables and relationships between measured attributes were prepared using Sigmaplot 12.5 or Origin 2019 software.

Results and discussion

Total organic matter ranged from very low (5 g C kg^{-1}) to very high (150 g C kg^{-1}). The C content of Gley soils was particularly variable (Figure 1). Organic matter content was greater in surface soils but did not differ ($P > 0.05$) between soil types. In the surface layer (0–10 cm), pasture soils had higher total C content than the maize soils (both soil orders).

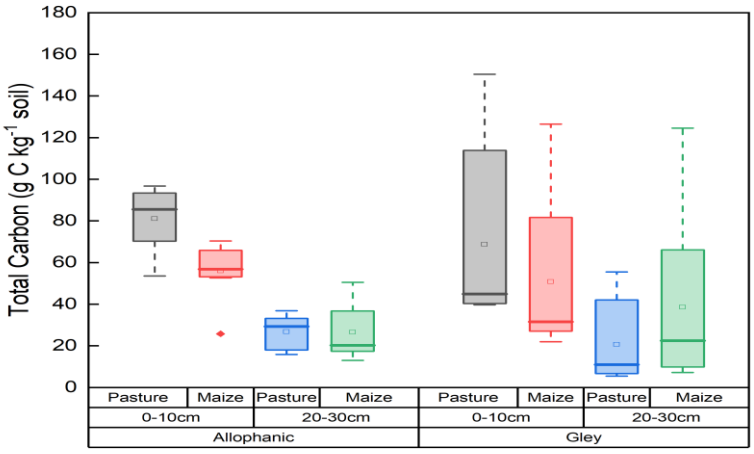

Figure 1. Total carbon concentration in the 0–10 cm and 20–30 cm layers under pasture and maize on Allophanic and Gley soils. In box plots the box indicates the range between the 25th percentile and 75th percentile (line within box indicates median); the whiskers extend to the 5th percentile and 95th percentile; and if the maximum or minimum is beyond that, it is marked with a dot.

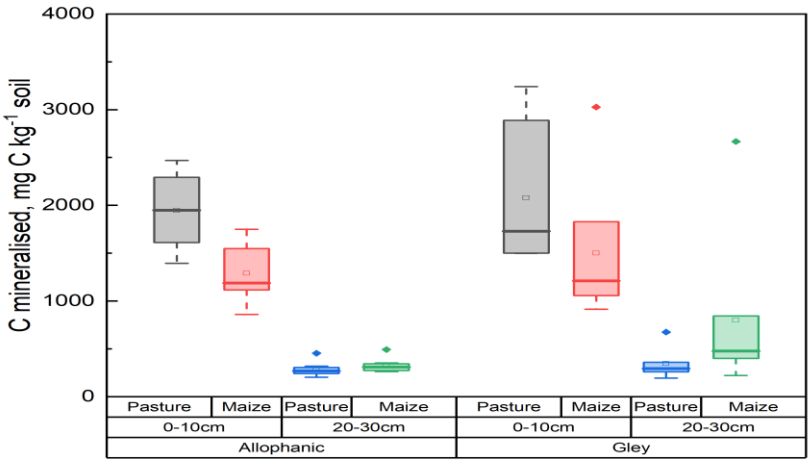

Figure 2. C mineralised (14-week incubation) in the 0–10 cm and 20–30 cm layers under pasture and maize on Allophanic and Gley soils.

As shown in Figure 2, mineralised C (14-week incubation) in surface soil was strongly influenced by land use, with pasture having higher values than maize soils (by 51 and 38%, respectively, for the Allophanic and Gley soil orders). This result is consistent with previous work showing that land use has a dominant influence on mineralisable C in topsoil (Curtin et al., 2017). In the deeper layer (20–30 cm), effects of land use were small, but with a tendency for maize soils to have higher C mineralisation values than pasture soils.

Our results suggested that organic matter in the Allophanic soils was more recalcitrant than that in Gley soils. In the surface layer, 2.4% of total C in Allophanic soils mineralised in 14 weeks compared with 3.4% in Gley soils (corresponding values for the 20–30 cm layer were 1.3% and 2.5%). Allophanic soils contain abundant imogolite and ferrihyrite minerals

(allophane) that may stabilise organic matter and protect it from decomposition by soil micro-organisms.

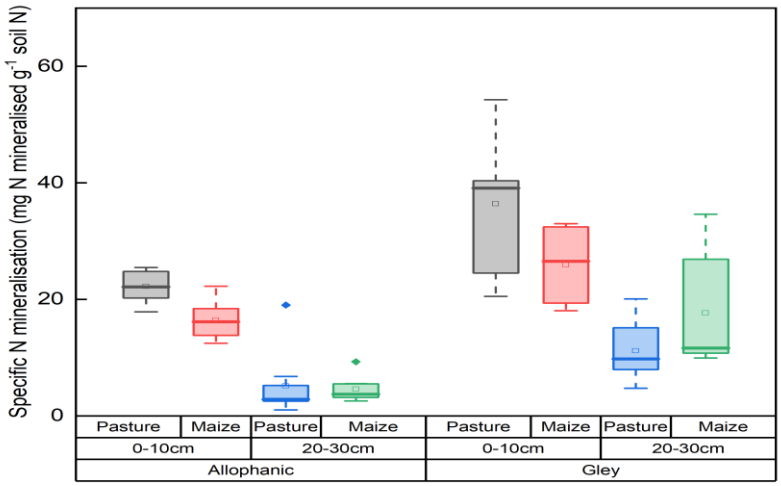

Figure 3. Specific N mineralisation (N mineralisation, normalised to total soil N) in the 0–10 cm and 20–30 cm layers under pasture and maize on Allophanic and Gley soils.

Specific mineralisation, the amount mineralised per unit of total organic matter, provides an indication of the vulnerability of soil C to loss and the susceptibility of N to mineralisation. At both depths, specific N mineralisation values of Gley soils exceeded those of Allophanic soils (Figure 3), again suggesting that SOM in Allophanic soils is more recalcitrant. Analysis of variance indicated that specific N mineralisation was also influenced ($P < 0.01$) by sampling depth. Pasture soils had significantly higher values than maize soils in the upper layer of both Allophanes and Gleys.

A previous study by Curtin, Beare, et al. (2017) suggested that the quantity of organic N extracted in hot water is comparable to the amount of N mineralised during a 14-week aerobic incubation at 25°C. In the present study, N mineralisation significantly correlated with total N ($R^2 = 0.72$), but it exhibited a closer relationship with hot water extractable organic N ($R^2 = 0.89$) (Figure 4), providing further support for adoption of the hot water extractable N test to predict mineralisable N.

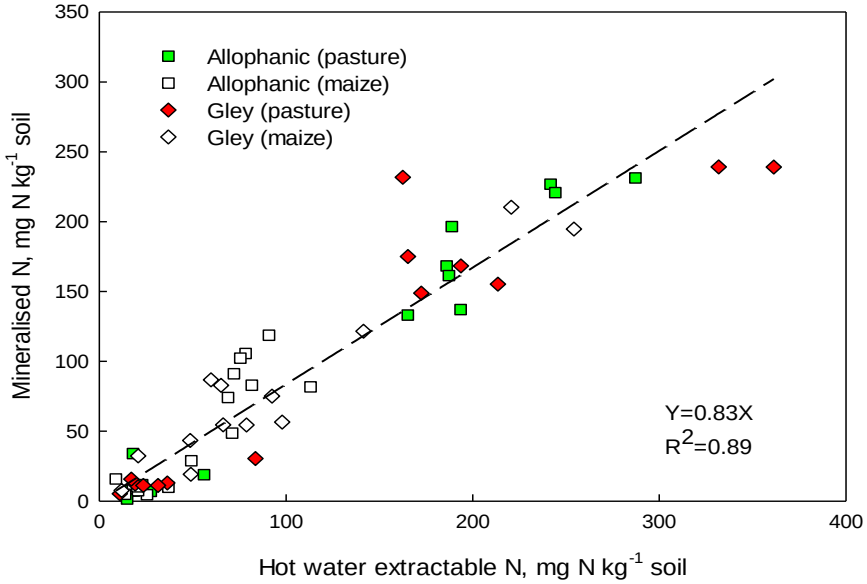

Figure 4. The relationship of hot water extractable N and mineralised N for Allophanic and Gley soils under pasture and maize production in the Waikato. Dashed line is fitted relationship for predicting mineralised N from hot water extractable N.

Conclusions

The results confirmed that land use history had significant effects on absolute rates of SOM mineralisation in the top layer, but there was no significant effect of soil type. However, after C and N mineralisation values were normalised to total C and N, soil type and soil depth were found to be more important than land management history. We conclude that both absolute rates of mineralisation and C and N specific rates of mineralisation provide useful and complementary information on the susceptibility of SOM mineralisation. We also concluded that hot water extractable N is a useful predictor for N mineralisation in Allophanic and Gley soils of the Waikato region.

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