How Does the Management-Induced Change in Soil Organic Matter Control Carbon Dynamics & Organo-Mineral Associations in a Volcanic-Ash Soil in Central Japan?

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Introduction

- Volcanic-ash soil, dominant soil type in Japan, holds significant amounts of soil organic matter (SOM) due to high stabilization capacity of its inorganic constituents.
- Yet, SOM destabilization (biodegradation) process and, in particular, its sensitivity to climate change (e.g., temperature increase) are not well understood.
- Literture suggests temperature dependence of SOM degradation (Q10) is linked to substrate quality (e.g., recalcitrance). Volcanic-ash soils are rarely studied, however.
- Here, we compared SOM dynamics using a volcanic-ash soil of the same mineralogy but with contrasting TOC contents (probably minimum & maximum end-members in surface soi environments) to elucidate the factors controlling Q10.

Objectives

- To assess the relationships among Q10 of microbial respiration (SOM degradation), microbial biomass, & various indices of substrate quality using bioassay, density separation, and ^{13}C-NMR approaches.

Soil Samples

Sample source: experimental fields at National Institute of Agro-Environmental Sciences, Tsukuba, Ibaraki, JAPAN. Soil classification: Hydric Hapludand. MAT 24°C. Precip 1300mm

Managment: 3 types of practices were applied to adjacent plots

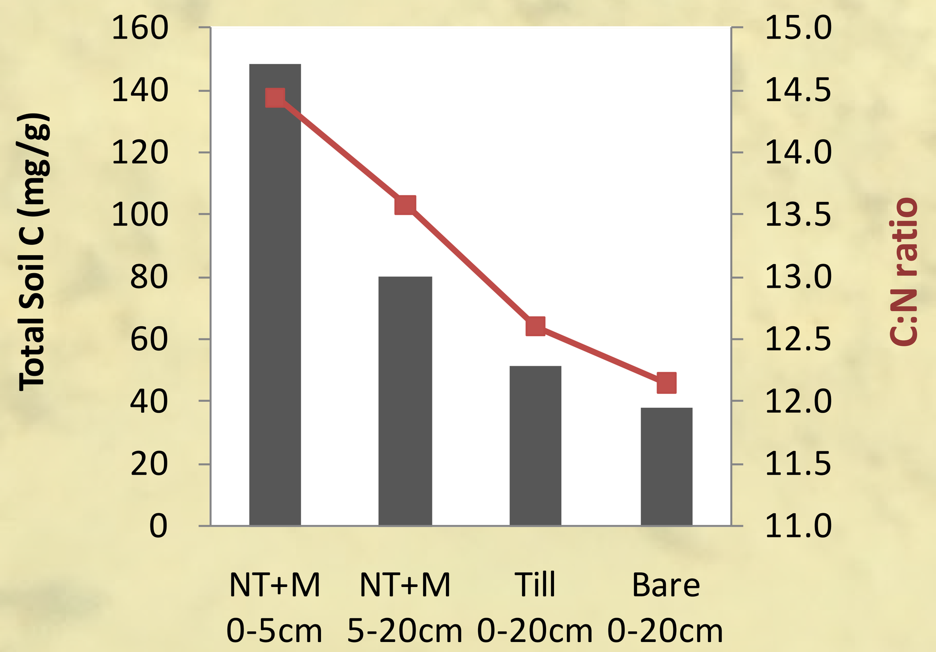
NT+M plot = 23 yrs of no-till plus annual leaf-manure addtions (soybean/winter wheat)

Tilled plot = tillage with inorganic fertilizer application (soybean/winter wheat)

Bare plot = no NPK fertilizer for decades & kept bare for the last 5 yrs

General soil characteristics

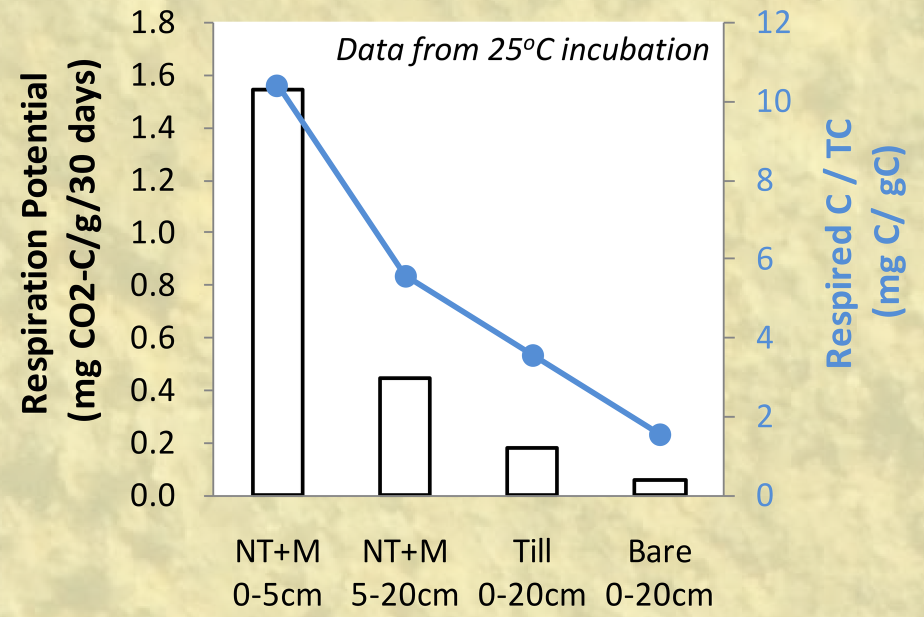
Management (sample ID)	Soil depth (cm)	Total OC (mg g^{-1})	pH in H_2O	Oxalate-extr Fe (mg g^{-1})	Oxalate-extr Al (mg g^{-1})	Oxalate-extr Si (mg g^{-1})	Pyrophosphate-extr Fe (mg g^{-1})	Pyrophosphate-extr Al (mg g^{-1})	Pyrophosphate-extr Si (mg g^{-1})
No-till+Manure	0-5 cm	148.5	6.16	10.1	19.8	10.7	0.8	1.4	0.5
No-till+Manure	5-20 cm	80.4	6.24	16.1	33.8	18.0	0.9	2.2	0.3
Till	0-20 cm	51.4	6.10	19.6	43.8	20.2	0.8	3.2	0.2
Bare	0-20 cm	36.9	6.50	20.0	40.3	19.7	0.1	2.4	0.1

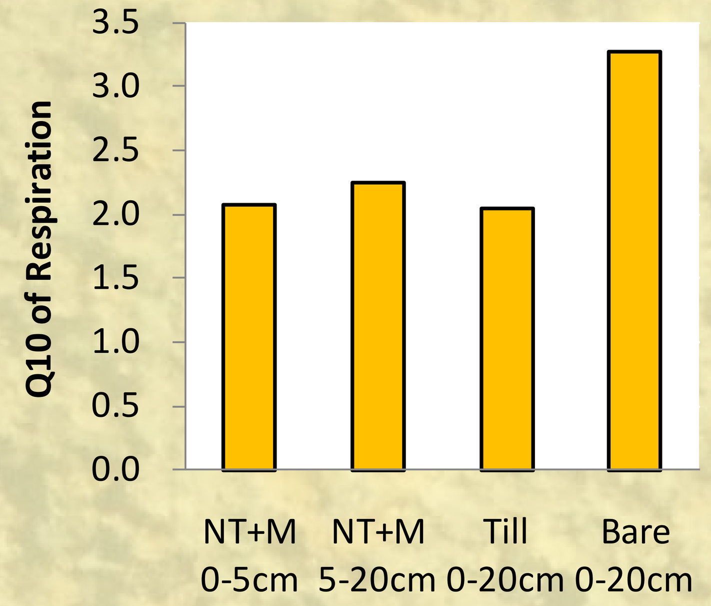


- NT+M soil was separated into two depth due to morphological difference and Fe /Al translocation
- Till and Bare soils had higher oxalate-extr Fe, Al in part due to surface erosion
- TOC, total N, and C:N ratio all declined from NT to Bare soil, largely reflecting the difference in OM addition by management

Incubation Experiment

METHOD: laboratory incubation (1 month at 15, 25, 35 °C) after 2-mm sieving and moisture adjustment to 60% of water holding capacity.

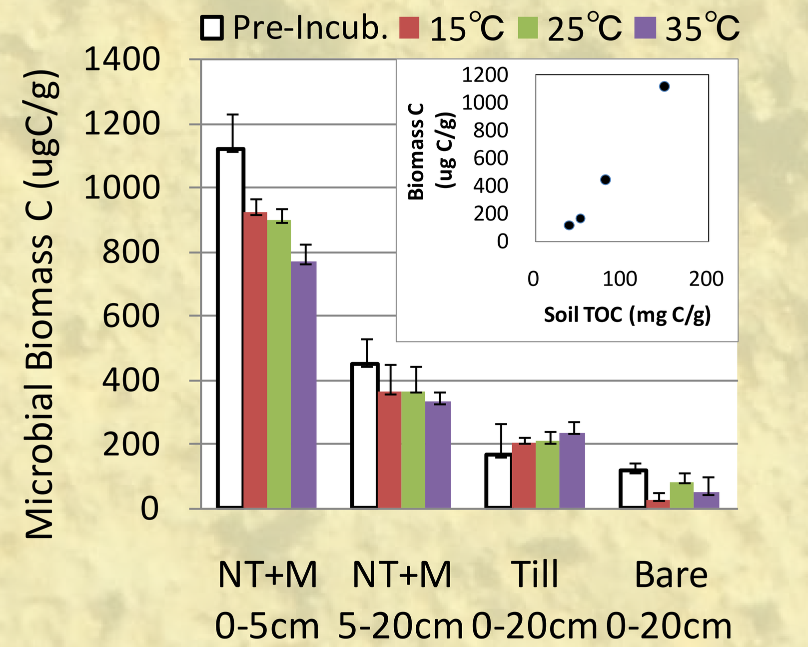




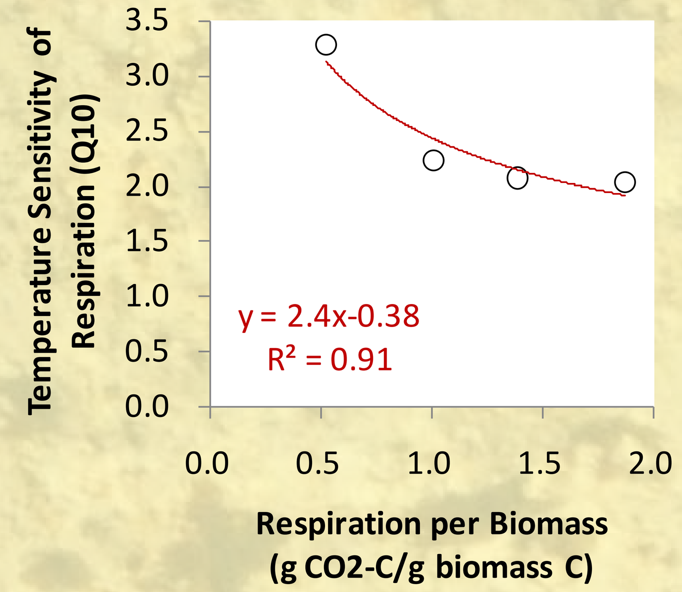
Despite linear decline in respiration and Resp C:TOC ratio, Q10 did not linearly increase!

Microbial Biomass

METHOD: Chloroform humigation/extraction (K_2SO_4) technique. Correction factor: 2.15



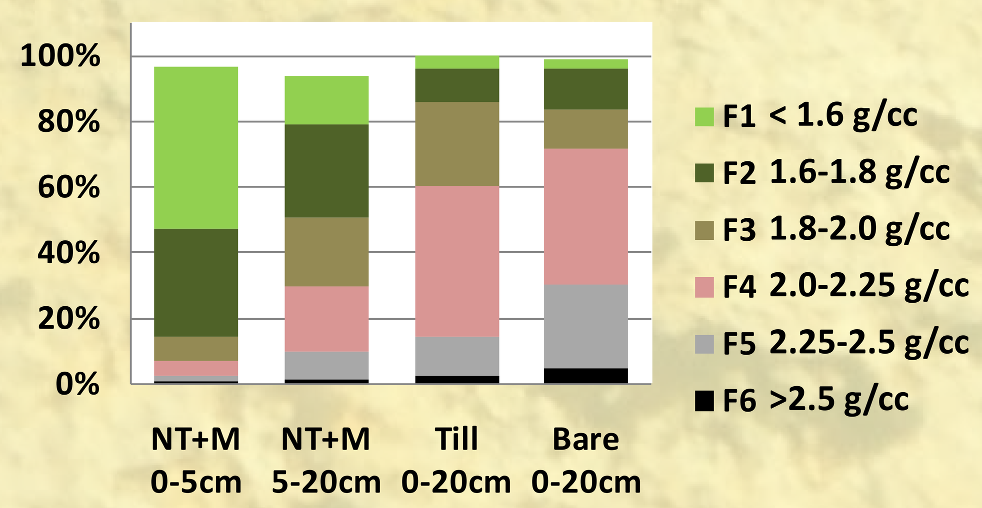
- Biomass C declined as TOC declined (above).
- Biomass-normalized respiration (right figure) was lowest in"Bare" soil, implying low substrate quality.



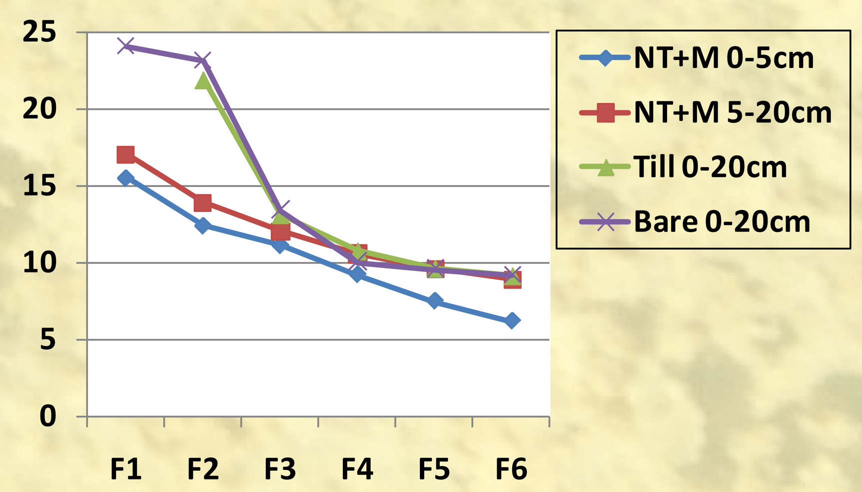
Biomass-normalized respiration seems a good index of substrate quality, accounting for Q10 variation in these soils.

Density Separation of SOM

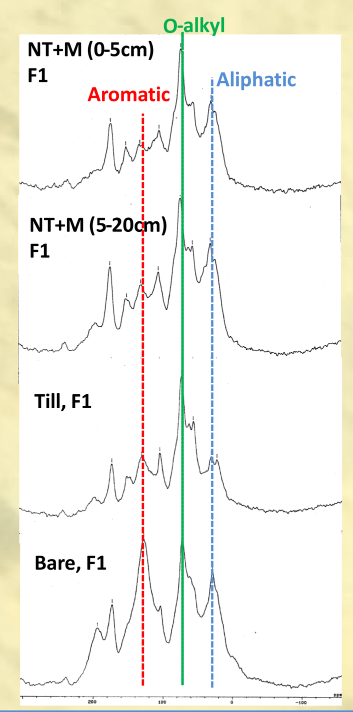
METHOD: Field-moist soils were mixed with sodium polytungstate solution of target density (first at 1.6 g/cc then heavier) and floatables are rinsed well with water and freeze-dried prior to chemical analyses.



➡ C in F1/TOC decrease from NT to Bare



➡ Unclear what high C:N of F1 in Bare mean



^{13}C-NMR spectra of F1 (<1.6g/cc)

Proportion of aromatic-C was much higher and that of O-alkyl-C was lower in "Bare" soil

F1 of "Bare" soil consists of more recalcitrant C than other soils

Summary

- With 3-fold decrease in TOC from "no-till/manure" soil to "bare" soil, microbial biomass C and following substrate quality indicies (soil C:N, respiration potential by 1-month incubation, and OC in low-density fraction) linearly declined.
- In contrast, Q10 of the respiration had non-linear response – all soils had Q10 of ∼2 except for "bare" soil (Q10 of 3.2).
- High Q10 of "bare" soil can be explained by low substrate quality, indicated by (i) low respiration per microbial biomass C and (ii) high aromatic-C/O-alkyl-C ratio of low-density fraction (<1.6 g/cc).
- In studied soils, apparent Q10 was surprisingly constant over a wide range of TOC levels (5-15% TOC). Below ca 4% TOC, substrate quality and microbial community appear to undergo significant change which leads to Q10 increase.

What controls Q10?

Arrhenius kinetics theory suggests Q10 is higher for low-quality substrate (more recalcitrant compounds). Soil incubation studies have shown results consistent with the theory. Then, ***what is the good measure of "substrate quality" in our soil?***

Substrate quality indices examined	Relationship with Q10
TOC, Bulk Soil C:N	×
Respired C	×
Resp C/TOC	×
Resp C/Biomass C	○
LF-C, LF-C/TOC	×
LF C:N, aromaticity	○

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