Diffusion limitation of methane oxidation in soils under long-term no-till

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Abstract

Adoption of no-till (NT) farming practices can improve the CH_4 oxidation capacity of croplands through creation of a favorable soil environment for methanotrophs, increased macro-porosity and better soil gas transport. However, there is still limited data to evaluate the merit of that contention. In addition, even though the potential for biological CH_4 oxidation may exist in NT soils, restricted diffusion could limit expression of that potential in fine-textured soils. Therefore, both the biological and physical components of CH_4 uptake must be determined. Using composite and intact cores from well-drained (MWD) and poorly-drained (PD) sites, a study was conducted to assess the CH_4 oxidation potential and gaseous diffusivity of soils under long-term (~50 y) NT and conventional plowing (CT). The NT soils exhibited higher maximum CH_4 oxidation (V_{max}) than CT. At the MWD site, the V_{max} of NT soil exceeded that of nearby forest soils. Compared to CT, CH_4 diffusion rate was on average 1.4 times higher in the NT soil. Results of this study will help address important questions regarding agricultural land management practices and climate change mitigation.

Objectives

- To characterize the methane oxidation potential of NT soils in comparison to CT and natural forest.
- To assess the significance of diffusion restriction on CH_4 oxidation in NT soils.

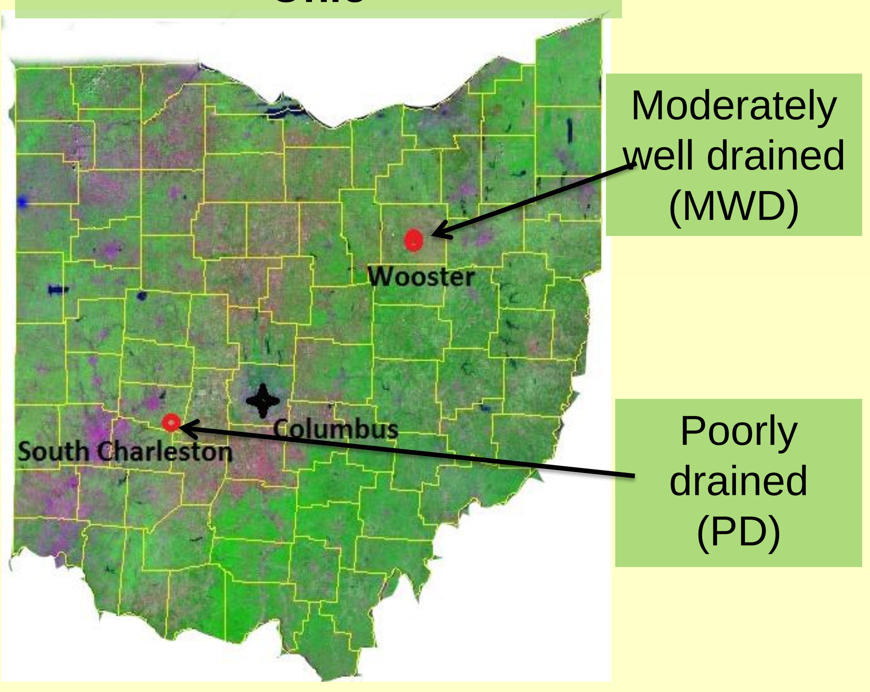
Hypothesis

- With absence of soil disturbance for a long period of time, it is hypothesized that a large and active population of methanotrophs will evolve, resulting in increased CH_4 oxidation.
- There will be increase in gaseous transport due to improved soil aggregation in NT compared to CT. Improvement in gas transport will be less significant in fine-textured and poorly-drained soils.

Methods

Location of study sites

Fig 1. Location of sites in Ohio



Soil Sampling

- Composite soil samples and intact soil cores were collected from CT, NT plots and woodlots at each site.


Fig 2. Intact soil core for determination of diffusion coefficients


Fig 3. Composite soil samples to assess CH_4 oxidation potential

Methane Oxidation Potential

- Field-moist and sieved (5 mm) soil samples were placed in Mason jar.

- Addition of methane (3 to 250 µl CH_4 L^{-1}) to jar headspace. (5 jars five level of CH_4).
- Rates of CH_4 oxidation was monitored over a 5-6 day period.

Fig 4. Soil incubation vessel. Air samples were taken with a syringe, stored in glass vials and analyzed for CH_4 using gas chromatography (FID – flame ionization detector)

- Kinetic parameters were determined using Michaelis Menten model:

$$v = (V_{max}[S])/(K_m + [S])$$

v = rate of CH_4 oxidation,(µg CH_4 kg^{-1} h^{-1})
V_{max}= maximum rate of CH_4 oxidation
K_m = half saturation constant (µl CH_4 L^{-1})
[S] = initial CH_4 concentration (µl CH_4 L^{-1})

Determination of Diffusion Coefficient

- Diffusion model for porous media proposed by Rolston et al. (1977) was used to calculate diffusion coefficient (D_s)

$$D_s = (KVL)/A$$

A = area of soil core;
V = the volume of diffusion chamber;
L = the thickness of soil sample.

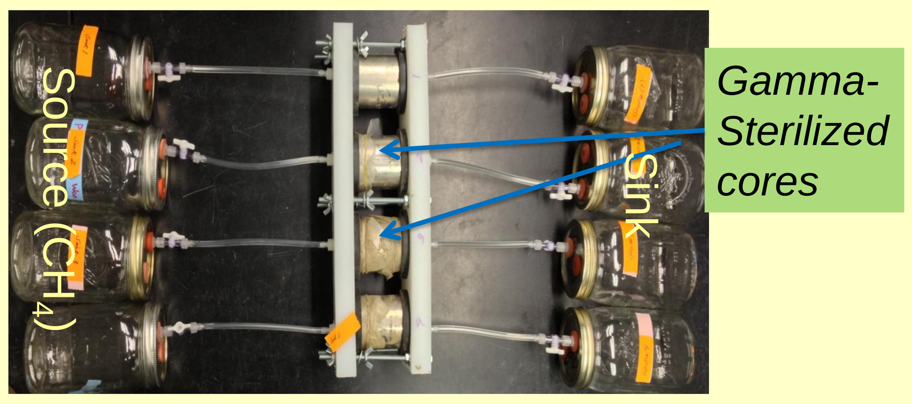
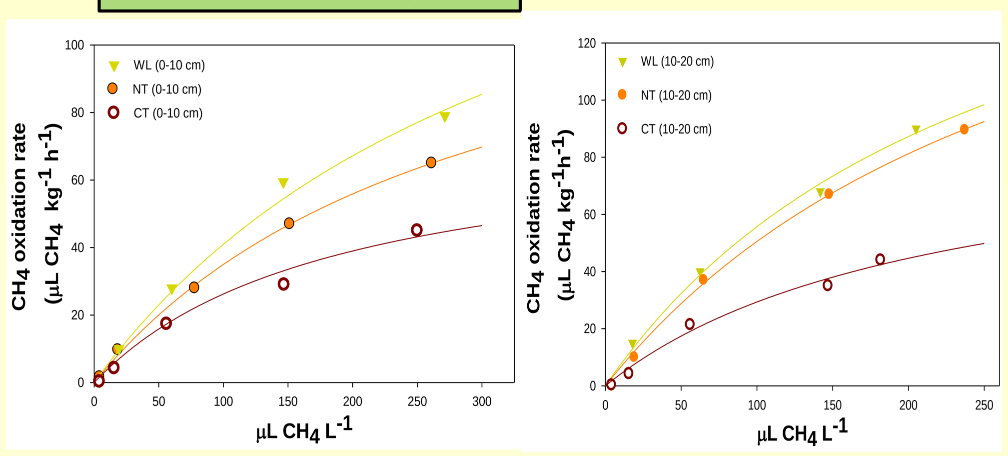


Fig 5. Diffusion apparatus

Results

Fig 6. CH_4 oxidation kinetics

S. Charleston, PD



Wooster, MWD

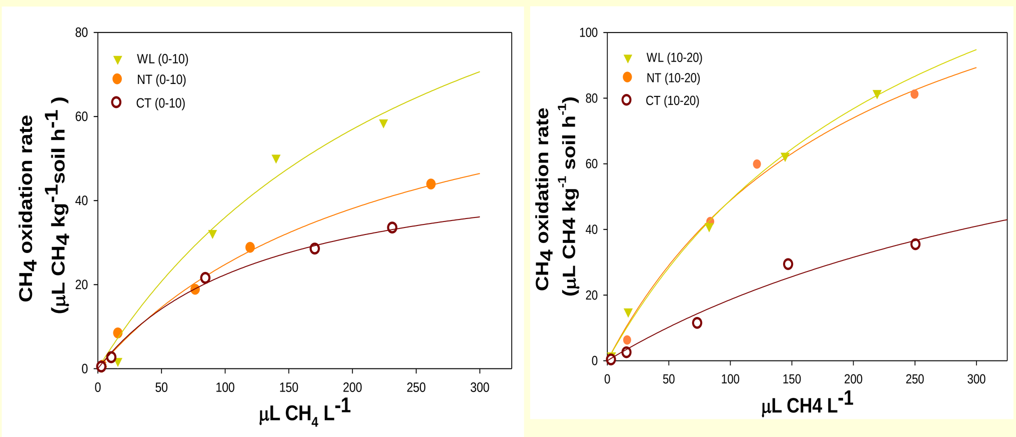
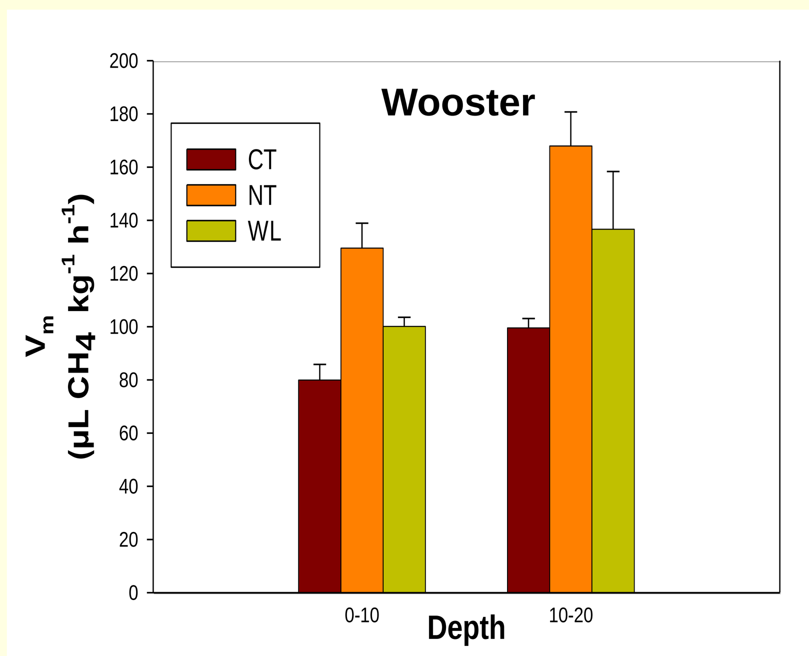


Fig 7. Maximum CH_4 oxidation potential in relation to tillage



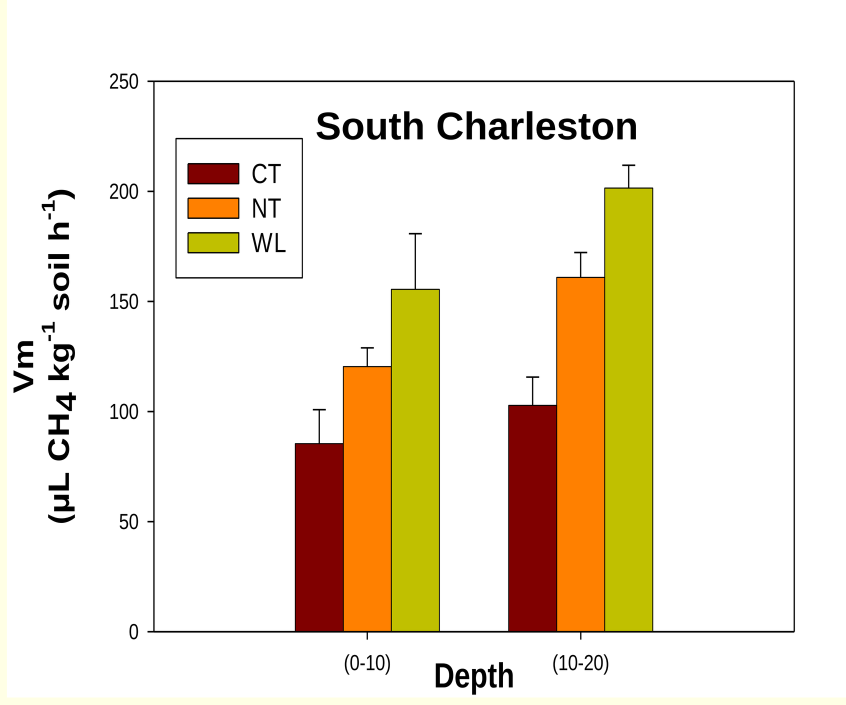
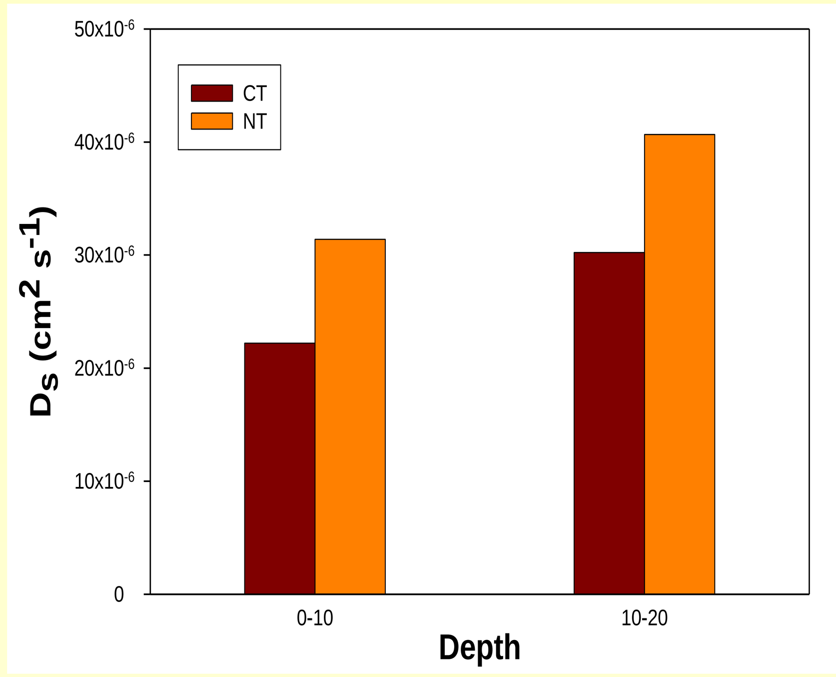


Table 1. Soil properties at the study sites

	Wooster			S. Charleston		
	CT	NT	WL	CT	NT	WL
Texture	silt loam	silt loam	silt loam	silt/clay loam	silt/clay loam	silt/clay loam
Bulk density (g/cm³)	1.085	0.97	0.88	1.525	1.58	0.94
*Soil moisture(%)	17.3	22.4	18.4	16	23	24.3
pH	5.7	6.4	5.57	6.1	6.46	6.27
MBC (mg MBC Kg^{-1} soil)	309	768	644	206	384	729
Organic carbon	14.1	22.0	24.5	22	30.0	71.2

** At the time of soil sampling*

Fig 8. CH_4 diffusivity (D_s) in soil in relation to tillage (S. Charleston)



Summary of Results

- The NT soils showed higher methane oxidation capacity (V_{max}) than CT soils (V_{max} in NT similar to forest soils). Results suggest the occurrence of favorable soil conditions for methanotrophs under NT.
- This interpretation is corroborated by measurements of higher soil organic carbon, and microbial biomass carbon (MBC) under NT.
- Preliminary results also showed higher (1.4 times) values for diffusivity (Ds) in NT compared to CT soils. Additional experiments will be conducted to determine the significance of gaseous transport and soil drainage characteristics on CH_4 consumption in cultivated soils.

References

- Bender, M., & Conrad, R. (1994). Methane oxidation activity in various soils and freshwater sediments: occurrence, characteristics, vertical profiles and distribution on grain size fractions. *Journal of Geophysical Resource, 99*, 16531-16540
- Rolston, D. E., & Brown, B. D. (1977). Measurement of soil gaseous diffusion coefficients by a transient-state method with a time-dependent surface condition. Soil Science Society of America. *Soil Science Society of America, 41*, 499-505.

Acknowledgements

Funding: USDA-National Research Initiative (NRI) grant 2009-35112-05213.