Response of Agricultural Soil Greenhouse Gas Fluxes to Amendment with Residual Waste Materials: Effects of Temperature and Moisture

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Introduction

Background

The growing need to lower the amount of organic waste materials deposited into landfills and released into the environment as pollutants, has led to the evaluation of residual waste materials (RWM) uses as agricultural soil amendments. In agricultural soils, RWM, alone or blended with a mineral nutrient source, can be used to counteract the loss of soil organic matter (SOM) and/or as a source of nutrients (Johnson et al., 2007). RWM add C and N to the soil, which affect physical, chemical, and biological properties and processes. These effects are partially controlled by environmental factors, like temperature and moisture, which influence the microbial processes that produce C and N-containing greenhouse gases (GHGs), including CO_2, CH_4 and N_2O.

Because water directly competes with air for pore space, soil moisture controls aeration and affects the diffusion of gases in the soil. Low soil moisture content leads to more opportunity for gas exchange between the soil and the atmosphere, allowing for greater diffusion of O_2 into the soil for consumption by microorganisms and plant roots, and greater release of CO_2 from the soil. Conversely, high soil moisture content restricts O_2 diffusion and slows the rate of aerobic microbial activity (Linn & Doran, 1984). High moisture content and O_2 diffusion support microbial production of CH_4 and its precursors, as well as denitrification.

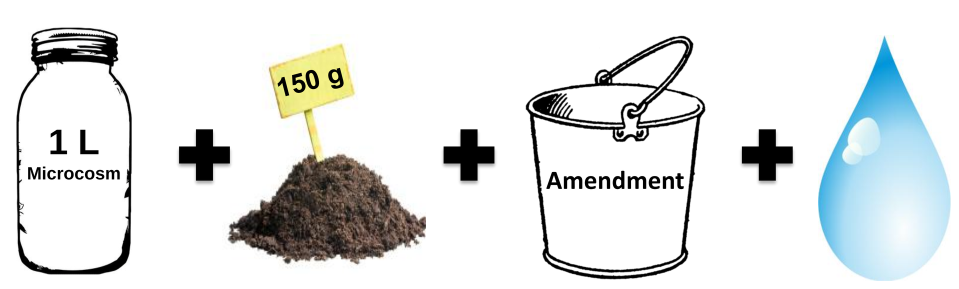
Soil moisture also affects the amount of energy needed to warm the soil, affecting soil biological and chemical processes. At low temperatures, the rate of most biological processes slow down, affecting the rates at which microorganisms make nutrients available. The rate of microbial processes, such as C mineralization, fermentation, methanogenesis, nitrification and denitrification, increase with the temperature. Thus, as temperature varies, so does GHG flux.

Objectives

- Examine greenhouse gas flux from agricultural soil amended with residual waste materials as a function of moisture and temperature.
- Observe effects of temperature and moisture on soil properties, and analyze the relationship between changes to soil properties and greenhouse gas flux.

Methods

Microcosms



*Amendments**

- Biosolids & Yardwaste Co-compost (BIO)
- Dehydrated Food Waste (DFW)
- Multi-source Compost (MC)
- Mineral Fertilizer (MF)
- Paper Fiber with Chicken Manure (7:1 ratio) (PF)
- Yardwaste Compost (YW)

*Applied at field-equivalent of 10 Mg C/ha or 560 kg/ha (MF)

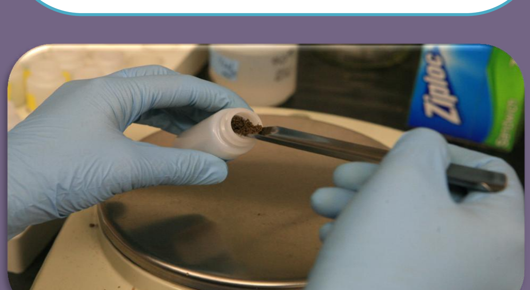
Moisture

- Permanent Wilting Point (10%)
- Field Capacity (25%)
- Saturation (44%)

Incubation

Microcosms were incubated for 14 days at the following temperatures

- 10 C
- 15 C
- 20 C
- 25 C



Sampling and Analysis

Microcosm Gases

- Collected each 2 days for 14 days

Soil Samples

- Taken on D0 and D14
- pH
- Electrical Conductivity
- Inorganic Nitrogen

Amendment Samples

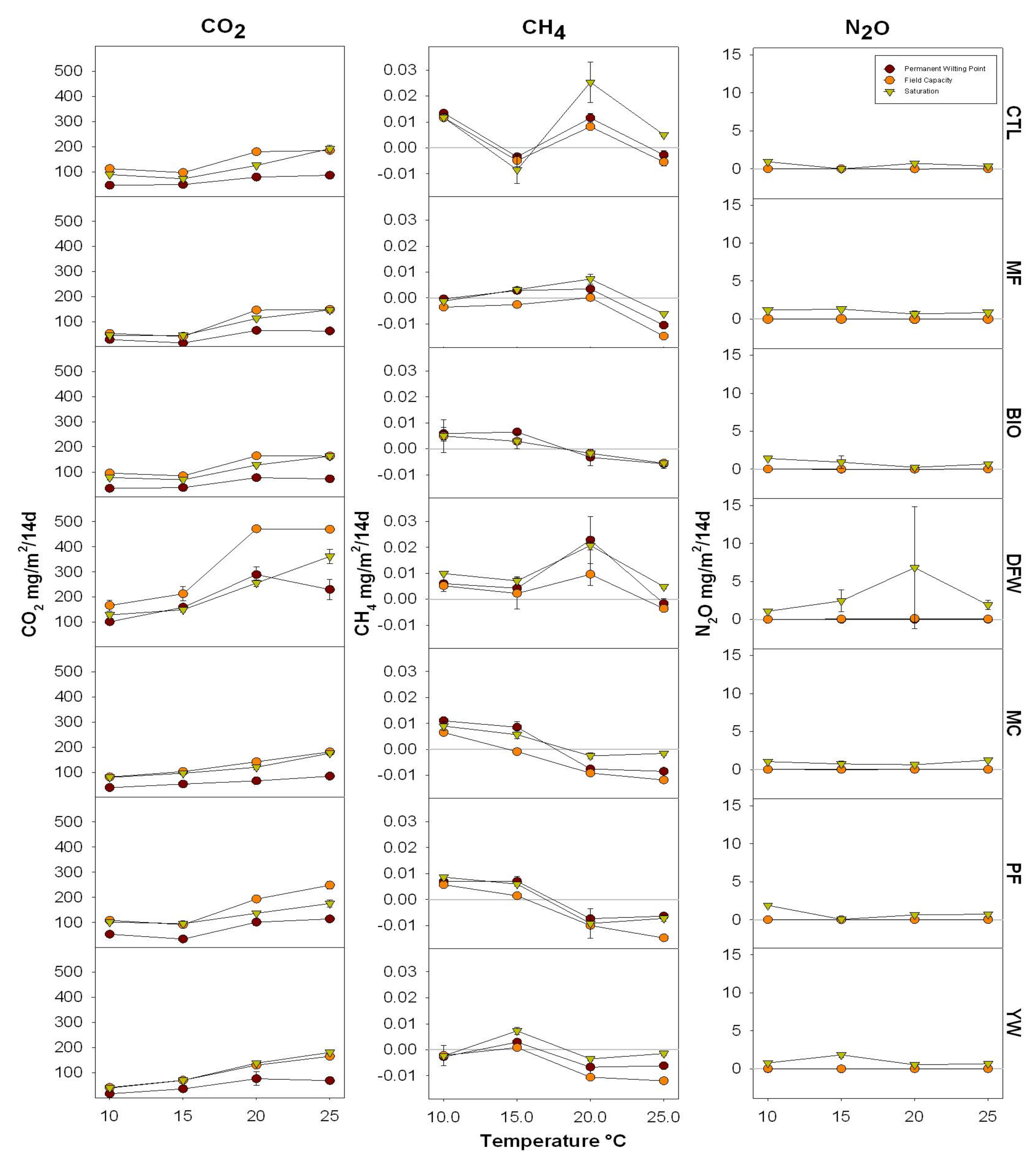
- Greenhouse gases
  - Once/day for 3 days at 25 C
- Active Carbon

Acknowledgments

- Rhode Island Agricultural Experiment Station
- Elizabeth Tewksbury & URI Greenhouse

Results and Discussion

Cumulative GHG Production



CO_2

- CO_2 production increased with temperature and had increased production from permanent wilting point to field capacity, but reduced production between field capacity and saturation.
- CO_2 production from DFW amended soil was significantly higher than CTL at all temp and moisture combinations.

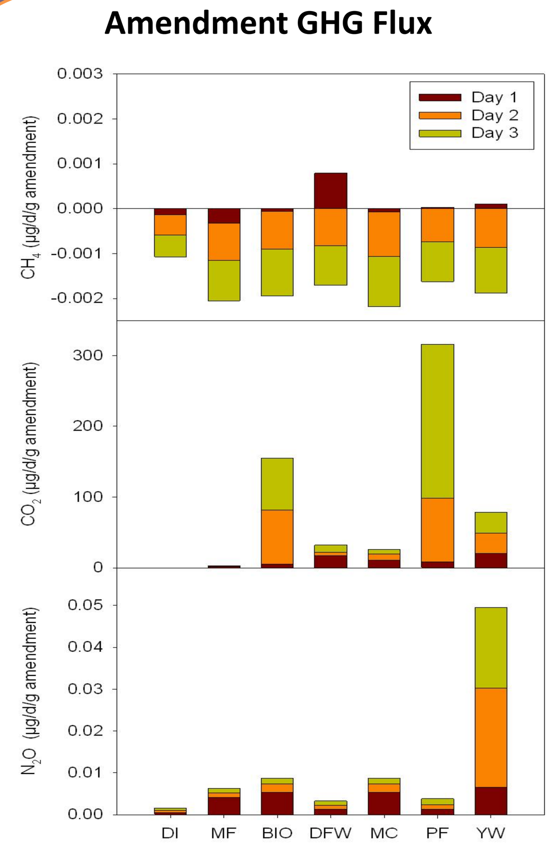
CH_4

- Cumulative CH_4 production had a trend of decreasing production/net consumption with increasing temperature.
- Saturated soil produced the highest flux of CH_4.
- CTL and DFW had net CH_4 production at 20 C, while all others experienced net consumption.

N_2O

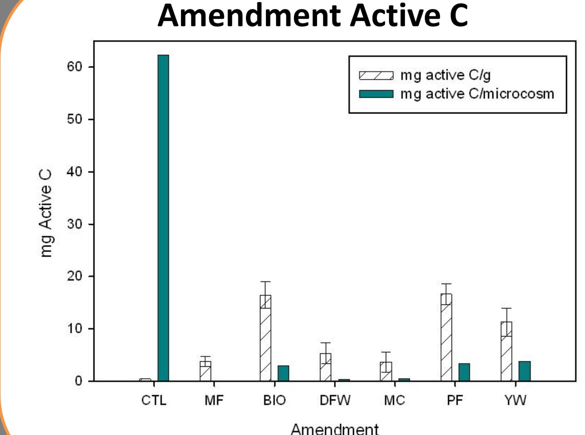
- N_2O production responded to moisture content with the most production at saturation, particularly from DFW.
- Many amendments produced N_2O flux higher than CTL, but most did not yield significant differences, except at saturation.

Amendment GHG Flux



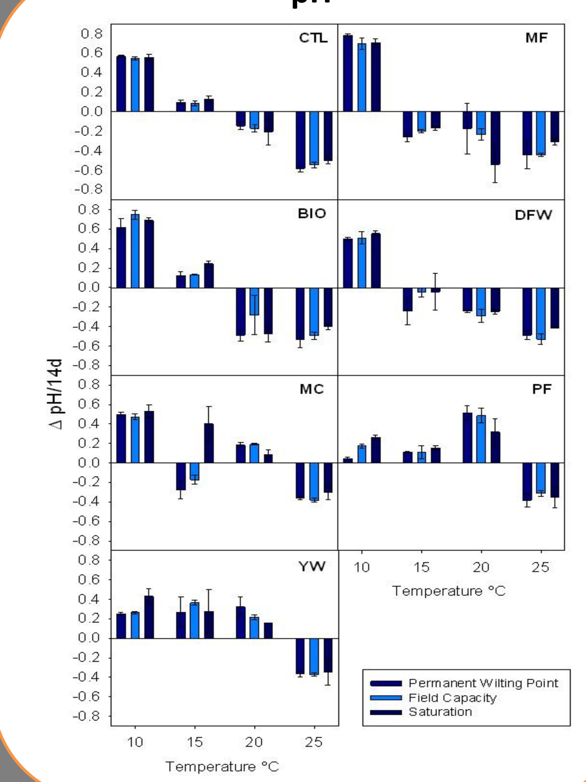
- All amendments resulted in net CH_4 consumption, suggesting the microorganisms associated with the amendments supported decreased production, increased consumption, or both.
- Yardwaste produced almost 5 times as much N_2O as the other amendments, but was not a problem in the amended soil.
- GHG flux from amendments account for less than 0.002% of GHG flux from amended soil.

Amendment Active C



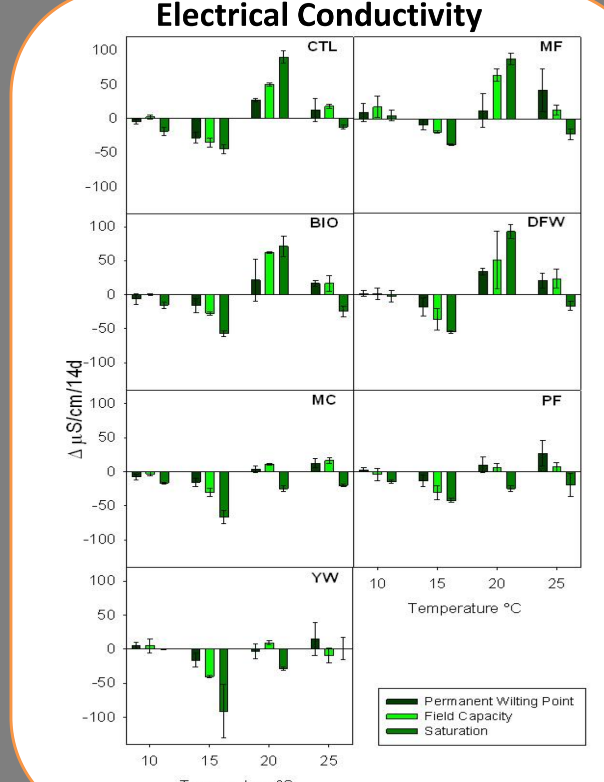
- Active C levels among the amendments varied but were not significantly different at application rates.
- The amount added was minimal compared to the ~63 g in the soil.
- Comparison of active C applied and cumulative CO_2 produced no relationship (r^2 = 0.0293).

pH



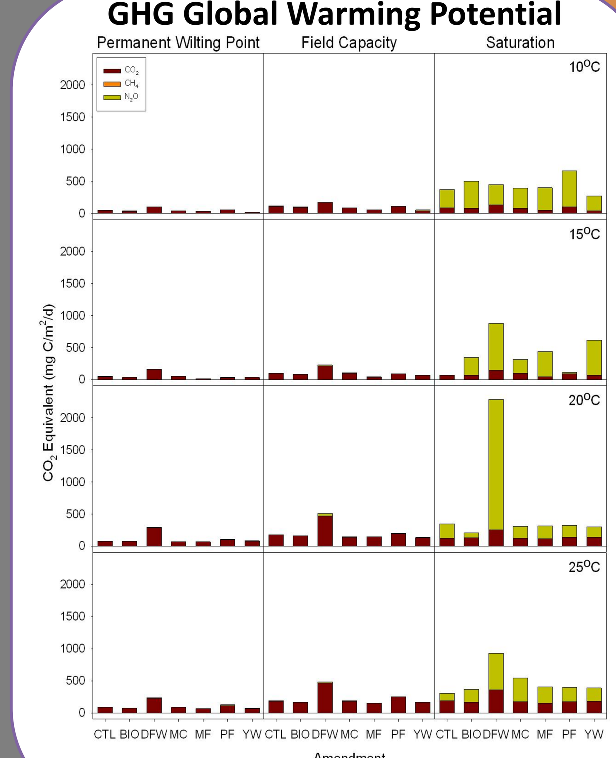
- Changes in pH were primarily affected by temperature, indicating biological effects.
- Temperature of acidification varied by amendment, suggesting some could provide a buffering effect.
- There is a negative relationship between increased pH and decreased CO_2 production (r^2 = 0.229), explainable by microbial sensitivity to soil pH.

Electrical Conductivity

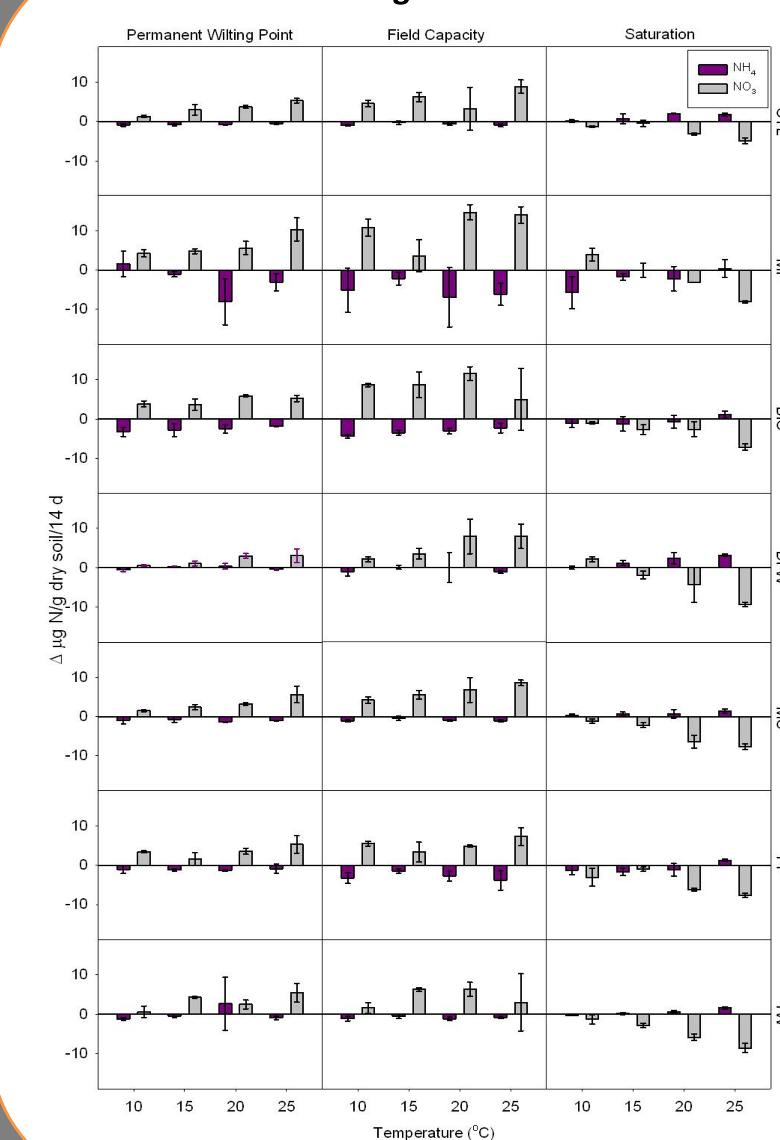


- Increasing moisture content had an amplifying effect on EC.
- Saturated soil produced largest changes.
- DFW had the highest increase at 20°C and YW the highest decrease at 15°C.
- No relation was found between change in EC and cumulative GHG production.

GHG Global Warming Potential



Inorganic N



- Generally, soil at permanent wilting point and field capacity had increasing levels of NO_3^- while saturated soil levels decreased.
- Increased temperature led to increased NH_4^+ levels in saturated soil, while NH_4^+ was lost at permanent wilting point and field capacity, regardless of temperature.
- MF had the largest changes with -8.06 mg NH_4^+-N/g/14d at 20°C permanent wilting point and 14.68 mg NO_3^--N/g/14d, at 20°C field capacity.
- There was a negative correlation between inorganic N and cumulative N_2O production (r^2 = 0.201) justified by the decrease in NO_3^- from samples at saturation, where incomplete denitrification caused by decreased O_2 diffusion is likely.

Conclusions

- DFW produced significantly higher CO_2, CH_4 and N_2O relative to the CTL, which could not be explained by amendment properties or the amendment's effects on soil properties.
- BIO, MC, PF, and YW resulted in net consumption of CH_4 when the CTL had net production, while not having a large impact to CO_2 and N_2O, suggesting benefits to GHG emission when used as soil amendments.
- Active C was not a reliable predictor of GHG production.
- The use of microcosms is a viable method for testing prior to application in a field setting.

Future Research

- Life cycle analysis for GHG production of amendments
- Identification of factors related to net methane consumption.
- Identification of additional processing techniques to reduce the effect of DFW on GHG production.

References

Johnson, J. M. F., A.J. Franzluebbers, S.L. Weyers, and D.C. Reicosky. 2007. Agricultural opportunities to mitigate greenhouse gas emissions. *Environmental pollution*, *150*:107-124.

Linn, D. M., and J.W. Doran. 1984. Aerobic and anaerobic microbial populations in no-till and plowed soils. *Soil Science Society of America Journal*, *48*:794-799.