Greenhouse Gas Emissions and Soil Quality in Long-term Integrated and Transitional Reduced Tillage Organic Systems

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Introduction

Besides producing high quality food, organic agriculture has the potential to provide environmental services that support soil conservation, reduce greenhouse gas emissions (GHG) and improve soil quality. Use of crop rotations, cover crops, and animal amendments in organic systems to enhance fertility also fosters soil quality and aids in the mitigation of GHGs due to the potential to sequester carbon (C). Critical knowledge gaps exist in on-farm and basic research that include the identification of best management practices (BMP)'s that retain C and N inputs from plant and animal amendments in soil and adaption of these identified (BMP)s across climatic conditions. Vegetable cropping systems are of particular interest because of the diversity of rotations, integration of cover crops, their reliance upon tillage and the possibility of integrating livestock in these diverse systems. Few studies have quantified the potential of vegetable production systems to sequester C and or adapt conservation tillage practices.

Our long-term goal is to have farmers adopt management practices that integrate cover crops, tillage practices, organic amendments and livestock to improve soil quality, utilize nitrogen efficiently and reduce greenhouse gas emissions from soil and farm machinery.

Objectives

1. Quantify and model GHG emissions and C sequestration in long-term and reduced tillage organic systems with varying manure application, crop rotation, and tillage intensity.

2. Identify and quantify, for example, the keystone microbial community members that control nitrification and denitrification in different organic farming systems.

3. Facilitate and evaluate the adoption of organic management practices that restore, maintain and enhance soil quality and contribute to climate change mitigation.

Design of Field Experiments

The field plots at WSU Puyallup encompass a range of organic vegetable production systems, including one with livestock integration. Three of the treatments for this experiment are within the Organic Vegetable Systems Experiment, which was established in 2003 and is approaching a mature organic system (Figure 1). The other two treatments are part of the new Organic Reduced-Tillage experiment and allow measurements within a system in a transitional phase (Figure 2).

Post-Harvest Cover Crop				Relay Cover Crop				30-month Pasture			
Com	BL	BL	Com	Com	BL	Com	BL				
Conv. Till		Spader Till		Conv. Till		Spader Till		Spader Till		Conv. Till	

Figure 1. Puyallup Organic Vegetable Production Systems Experiment.
One of four replicates. Com = mixed compost amendment; BL = Broiler litter amendment. Shaded treatments will be evaluated for greenhouse gas emissions.

Squa	Broc	Bns	Broc	Squa	Bns	Broc	Bns	Squa	Squa	Broc	Bns	Squa	Broc	Bns
flailing + no-till			flailing + zone till			flailing + complete till			roll/crimp + zone till			roll/crimp + no-till.		

Figure 2. Puyallup Organic Reduced Tillage Experiment
One of four replicates. Squa=squash; Broc= broccoli; Bns = beans. Shaded treatments will be evaluated for greenhouse gas emissions.

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Identification of Best Management Practices

Agricultural systems are a source of three GHGs: carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). The development of management strategies that sequester C and improve nitrogen use efficiency (NUE) in organic systems can reduce GHG emissions of CO_2 and N_2O.

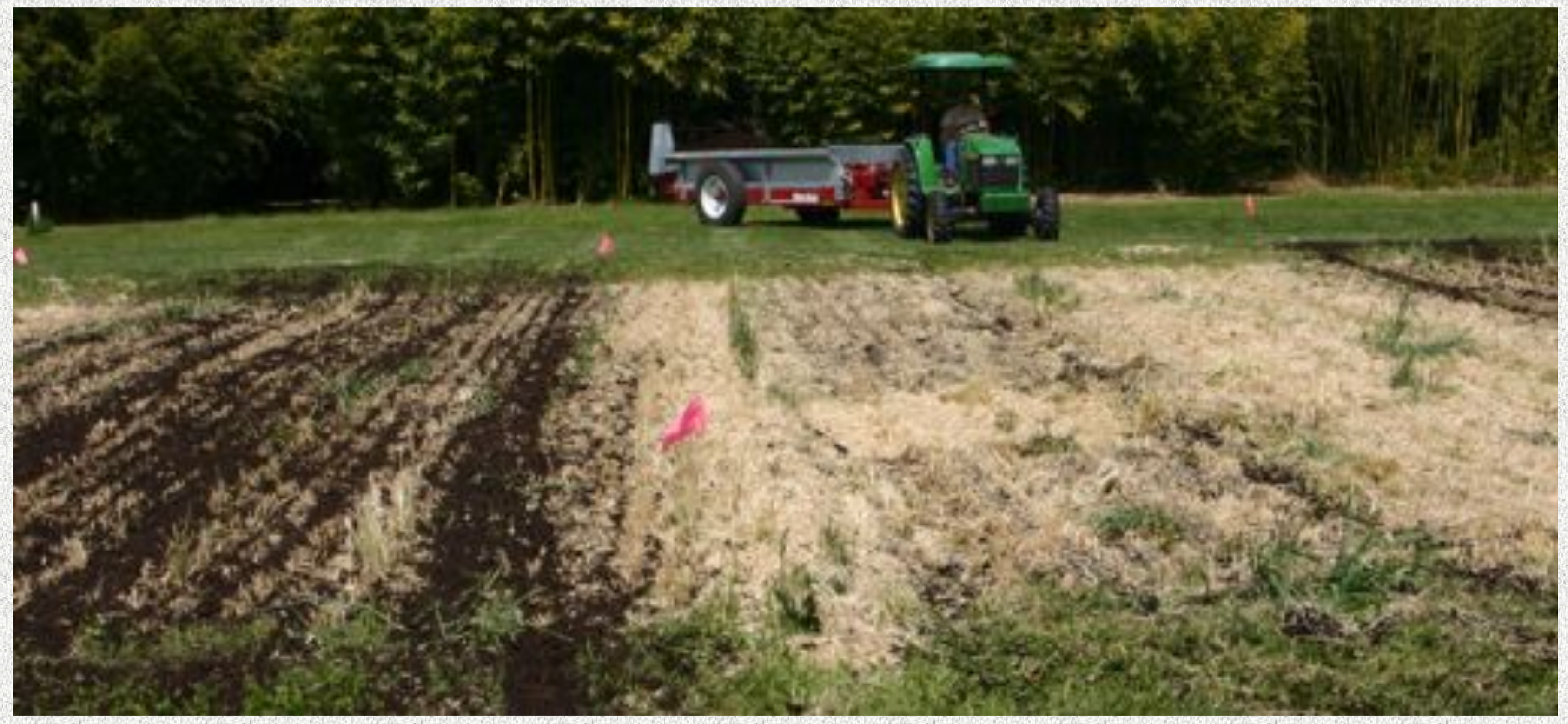

Figure 3. Applying mixed compost (left) and broiler litter amendment (right) in the Organic Vegetable Production Systems Experiment.

The *Long-term Organic Vegetable Systems Experiment* was established at WSU Puyallup in 2003. Treatments provide contrasts in organic carbon additions, tillage intensity, and duration of the cover crop cycle. Cover crop treatments include 1) a fall-seeded cereal rye-hairy vetch mix; 2) relay-intercropped hairy vetch planted into the cash crop; and 3) a short-term pasture (ley) planted to a mixture of annual ryegrass, perennial ryegrass, red clover, and white clover. The pasture rotation treatment has received no amendment since 2005. Sheep and poultry are raised on the pastures in a rotational grazing system. Vegetables are grown every year in the fall seeded and relay treatments, and every third year in the pasture treatment. Soil amendments include N-rich broiler litter applied at 4-6 Mg/ha/yr, and C-rich mixed compost applied at 14-18 Mg/ha/yr. This study focuses on 3 treatments (12 field plots) in two cover crop managements: the fall-seeded cereal rye-hairy vetch mix with 1) broiler litter and 2) mixed compost amendments (both with spader tillage), and 3) the 30-month pasture.

Figure 4. The reduced tillage plots in the Organic Reduced Tillage Experiment are managed by terminating cover crops with a roller/crimper (a) then disturbing soil for transplanting with a custom tool (b) that leaves a 5 cm wide by 10 cm deep swath (c).

The *Organic Reduced Tillage Experiment* was established in 2011. Main plots include a combination of cover crop termination (e.g. roller/crimper) and tillage type and plots are split by cash crop (Figure 2). The treatments being evaluated for this experiment are: 1) flailing + complete till, squash and 2) roll/crimp + no-till, squash. All plots are tilled in the fall of each year before planting the cover crop. Cover crops will be flailed or rolled/crimped. The complete till treatment is tilled with a spader. In no-till plots we will cut residue and disturb a 5 cm wide, 10 cm deep swath of soil with a custom-built tractor-drawn tool then transplant squash.

Measuring Trace Gas Flux

Trace gas measurements were taken from treatments in both field experiments in 2013 and will be taken again in 2014. Measurements are timed to characterize specific management events such as amendment application, tillage, and irrigation (Tables 1 and 2). Measurements are taken using the GRACENet protocol (http://www.ars.usda.gov/research/Gracenet), with chambers measuring 49.5 x 29 x 12.5 cm (h) (Figure 5). Nitrous oxide and CO_2 samples were analyzed on a gas chromatograph and a set of N_2O and CO_2 standards were used for standard curves.

Table 1. Gas sampling dates in Organic Vegetable Systems plots (a) and Organic Reduced Tillage Experiment (b) at WSU Puyallup, 2013.

Date	Management Event	Days
14Jan13	Frozen at 5cm	0
23Jan13	Thawed	0
17Jun13		-1
18Jun13	Amendment, tillage	0
19Jun13		1
20Jun13		2
21Jun13		3
25Jun13		7
3Jul13		15
16Jul13	Irrigation	0
17Jul13		1
18Jul13		2
20Sep13	Postharvest	0
27Sep13	Postharvest, tillage	0

a

Date	Management Event	Days
3Jun13		-1
4Jun13	Tillage	0
5Jun13		1
7Jun13		3
11Jun13		7
19Jun13		15
23Jul13	Irrigation	0
24Jul13		1
25Jul13		2
18Sep13	Postharvest	0
10Oct13	Postharvest, tillage	0

b

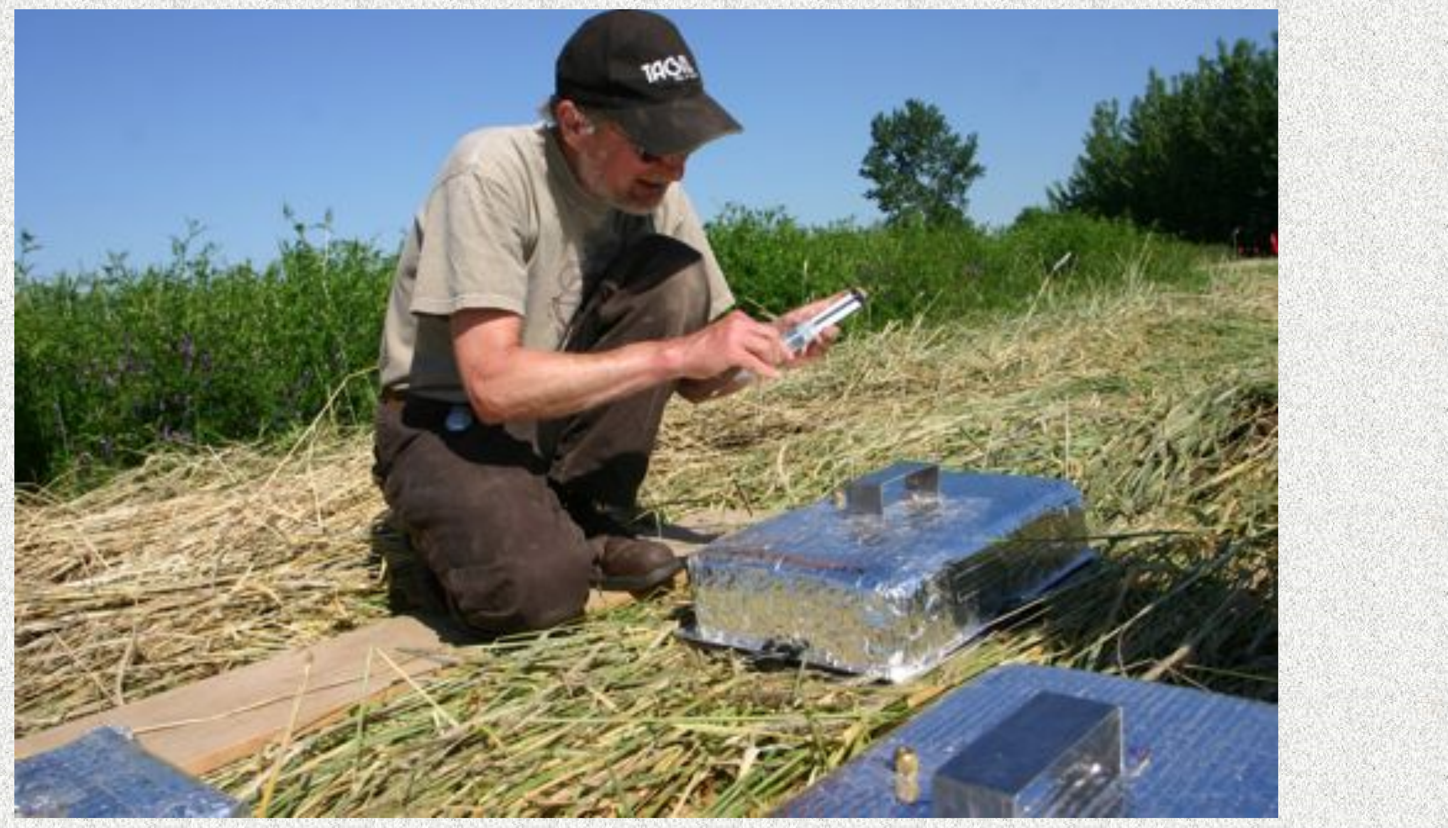

Figure 5. Sampling gas for nitrous oxide and carbon dioxide flux measurements from chambers in reduced tillage organic plots.

Microbial Community Composition

Soils were also sampled in conjunction with gas samples (Table 1) for inorganic N (0-15 and 15-30cm) and microbial community composition (0-30 and 0-10cm). The nitrifier and denitrifier community composition is being analyzed using pyrosequencing, gene copy number, and estimates of community size via quantitative polymerase chain reaction (qPCR) and activity by reverse transcription-PCR (RT-PCR) analyses. We are using pyrosequencing, qPCR, and RT-PCR to help identify microorganisms most commonly associated with high or low GHG emissions. Pyrosequencing will provide us with sequence libraries of each set of communities, qPCR will provide an estimate of gene copy number associated with each community, and RT-PCR will provide an estimate of the activity of each functional gene. Quantitative-PCR is used to provide quantitative information with respect to the size of a community and its growth response in the presence of amendments and environmental conditions.