The effects of intensification on nitrogen dynamics and losses on diversified organic vegetable farms

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Abstract
Nitrogen (N) is the main limiting nutrient, and is both a great driver of yield as well as agriculture's impact on the environment. Organic farming systems are subject to N losses and have less predictable N dynamics than conventional systems. The objective of this study is to compare the N dynamics and key loss pathways in three farming systems, including two organic systems, representing a gradient of intensification (characterized by quantity of inputs, and the frequency of tillage and fallow periods) in Kentucky, USA. We have grown spring planted table beet (*Beta vulgaris*), summer planted green pepper (*Capsicum anuum*), and fall planted collard green (*Brassica oleracea var. medullosa*). Soils were sampled monthly for soil mineral N (NH_4^+ and NO_3^-) at 0-15 cm, 15-30, and 30-50 cm depths. Trace gas fluxes (N_2O and CO_2) were measured weekly using a FTIR-based field gas analyzer. The results of this study showed the higher N_2O and CO_2 fluxes at the time of fertilizer application and tillage, at the beginning of the crop season.

Key Words
Nitrogen and carbon cycling, trace gases, N leaching, cover crops, vegetables,

Introduction
Nitrogen (N) is the main limiting nutrient for producing crops, and is both a great driver of yield as well as agriculture's impact on the environment. Soil Carbon and Nitrogen cycles are very dependent to each other. Higher amount of N fertilizer is being used throughout the world for producing higher yield, that leads to higher losses to the soil and water bodies through leaching or in to the environment as nitrous oxide and ammonia emission. Agricultural soil management practices were the largest source of nitrous oxide (N_2O) mission in the United States, accounting for 74.2% of total N_2O emission (EPA, 2015). Agriculture is both source and sink of greenhouse gases. So, informed management may influence greenhouse gas fluxes. The effect of N losses from agricultural management practices via greenhouse gas emissions and leaching losses have been broadly characterized in agronomic crop production. Vegetable production systems are more diversified in terms of crop use and input use than agronomic crop production system and it receives more amount of N fertilizer per unit area than grain crops and more frequently (Ju et al., 2009), as vegetables have generally short growth duration and high nitrogen requirement. Vegetables are irrigated frequently throughout the growing season, so we may expect frequent wetting and drying cycles than grain crop production (Kusa et al., 2002., Sehy et al., 2003), also likelihood of affecting greenhouse emission. They have been studied to a much lesser extent in vegetable production systems, perhaps due in part to the variability in the intensity of vegetable production practices. Given the intensity inputs, tillage and other resources, be they conventional or organic, and the growing interest in the sustainability of these systems, further investigation of these key loss pathways to the environment is warranted. Organic farming systems are subject to nitrogen losses; however, they are also subject to less predictable nitrogen dynamics than conventional systems, given the majority of nitrogen applied in these systems is from biologically-based amendments and nutrient availability is microbially-mediated. The goal of this work is to improve our understanding of the N and carbon (C) inputs, outputs, and the key pathways driving agroecosystem sustainability in horticulture-based systems along a gradient of intensification. The objective of this study is (i) to compare the nitrogen dynamics and key loss pathways in five farming systems, including four organic systems, representing a gradient of intensification (characterized by quantity of inputs, and the frequency of tillage and fallow periods) and (ii) to identify the sensitivity of measurement of the parameters to describe the key plant growth and soil processes.

Methods
The field experiment was initiated in 2014 at the Horticulture Research Farm, University of

Kentucky, Lexington, KY, and a cooperating farm in Georgetown, Kentucky. Three systems were studied in this work as described in Fig 1. Each system had replicated six times.

System description

	Extensive Organic	Conventional	Stationary Organic High Tunnel
			
Production	Seasonal*	Seasonal*	Year-round
Fallow Periods	5 year forage-based fallow, with rotational grazing	Annual cover crop once per year	None
Tillage Frequency	None (fallow) -> Intensive semi-annual primary and secondary (horticulture)	Semi-annual primary and secondary tillage	Quarterly secondary tillage, frequent cultivation for weed control
Nutrient inputs	Fallow, cover crop, minimal compost	Cover crop, synthetic fertilizer	Compost, granular manure-based fertilizer
Intensification	Low		High

Fig 1: System description based on level of intensification

We have grown table beet (*Beta vulgaris*) in spring, green pepper (*Capsicum anuum*) in summer, and collard green (*Brassica oleracea var. medullosa*) in fall. Soils were sampled monthly for soil mineral N (NH_4^+ and NO_3^-) at 0-15 cm, 15-30, and 30-50 cm depths. Trace gas fluxes (N_2O, NH_3, CO_2, and CH_4) were measured weekly using a FTIR-based field gas analyzer (Gasmet Technologies, Finland). The rectangular metal gas pans were installed at the beginning of the cropping season in each crops and kept throughout the season. We placed the rectangular receiver on the pan for 10 minutes.

Results and Discussion

Preliminary CO_2 and N_2O fluxes measured during the 2014 main growing season indicate consistently higher N_2O and CO_2 fluxes in the Extensive Organic system. The Organic High Tunnel system had intermediate CO_2 flux levels, and the lowest N_2O fluxes of the three systems. The Conventional system had the lowest CO_2 flux levels, with intermediate N_2O fluxes. Fluxes peaked in all systems in June with declining rates through late summer and fall. Preliminary leaching data indicate the Conventional system may be exhibiting greater mineral N loss rates than the other study systems.

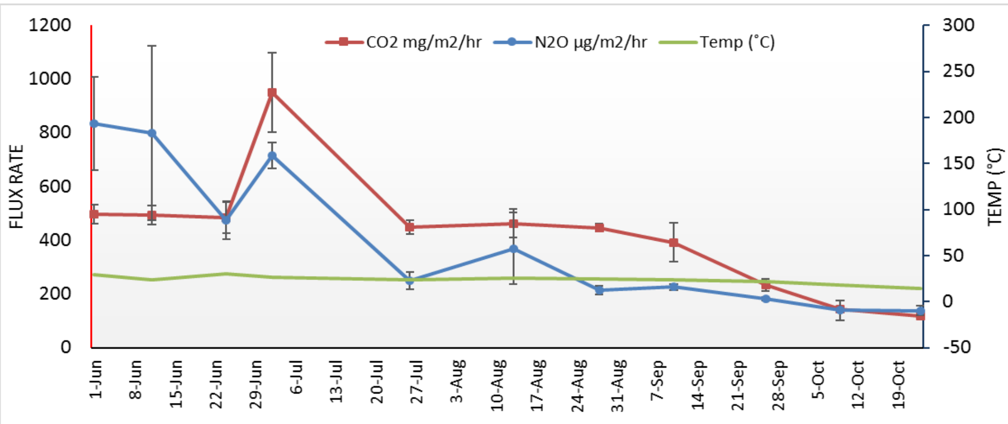

Fig 2: CO_2 and N_2O flux in Extensive organic system during 2014 main growing season

In Conventional system and High Tunnel system, CO_2 and N_2O fluxes give a rise at the starting of the September, it is due to the application of fertilizer, tillage and planting of crops for winter season. Soil nitrate content seen higher in the time period of high nitrous oxide fluxes, that is generally seen at the beginning of planting after tillage and fertilizer application. The fluxes may be affected by soil water potential, which could be better explained after complete data analysis.

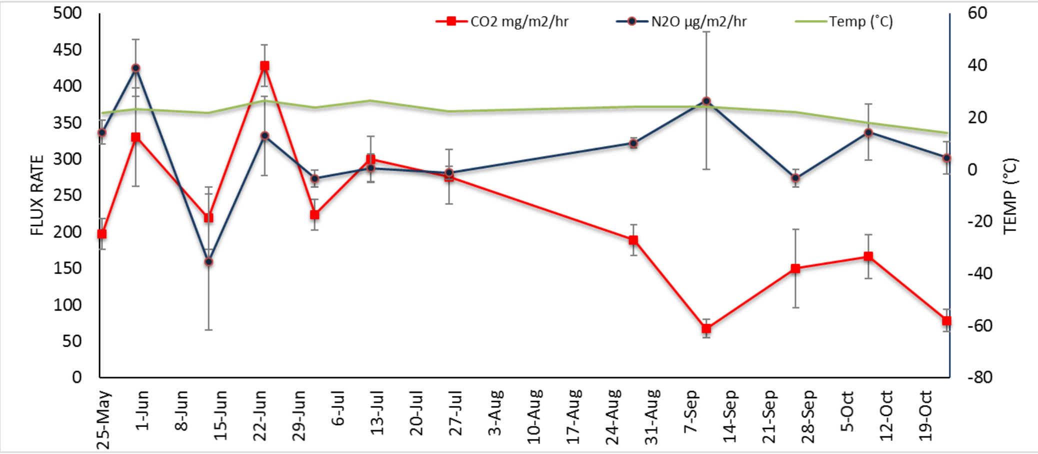

Fig 3: CO_2 and N_2O flux in Conventional system during 2014 main growing season.

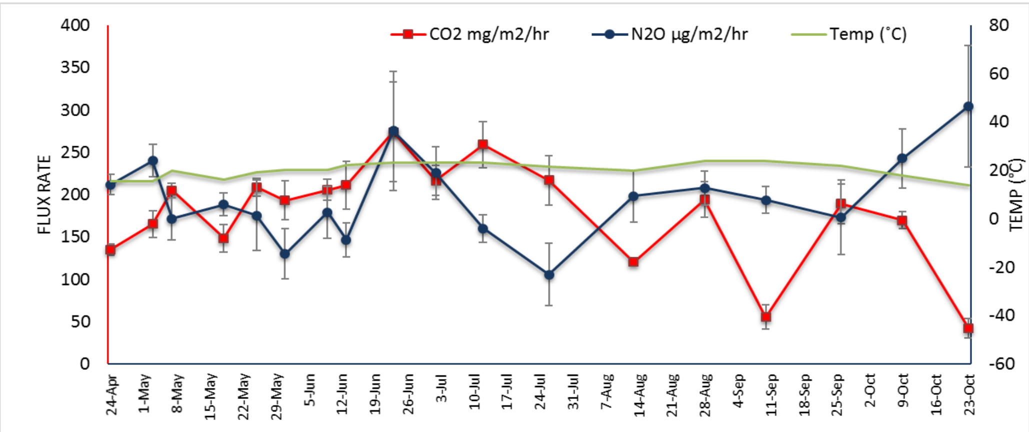

Fig 4: CO_2 and N_2O flux in High tunnel organic system during 2014 main growing season.

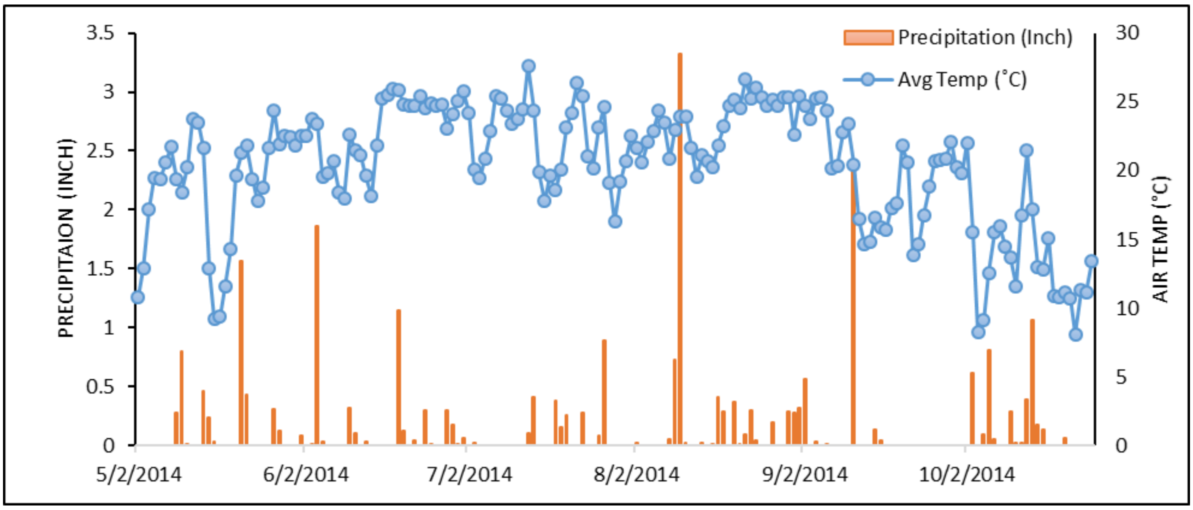

Fig 5: Daily precipitation and average temperature data during 2014 main growing season.

Conclusion

Preliminary results indicate that the level of intensification as characterized by this study may influence N losses to the environment via trace gases and leaching. However, it is important to view these field-scale results in the context of whole farming system metrics when assessing environmental sustainability of such systems. Future work will include one additional years of field data, include other soil- and plant-based parameters to characterize labile N and C cycling in these systems and modelling to improve understanding plant growth and soil processes.

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