The Effect of Intensification on Nitrogen Losses from Diversified Vegetable Farms

Debendra Shrestha[1], Krista Jacobsen[1], Ole Wendroth[1] and John Schramski[2]
(1)University of Kentucky, Lexington, KY, (2)University of Georgia, Athens, GA

Introduction

Nitrogen (N) is a major agricultural input that is critical for crop production. Human induced production and release of reactive nitrogen has greatly affected the earth's natural balance of N, contributing to changes in ecosystems, over-enrichment of aquatic ecosystems, biodiversity losses, and global climate change (e.g. Ribaudo et. al., 2011).

Agricultural soil management practices such as fertilizer application and other cropping practices were the largest source of nitrous oxide (N_2O) emission in the United States, accounting for 74.2% of total N_2O emission (EPA, 2015). Other key loss pathways include nitrate (NO_3^-) leaching losses to the soil and water environment, with well documented subsequent effects on surface and ground waters.

The effect of N losses from agricultural management practices via greenhouse gas emissions and leaching losses have been broadly characterized in agronomic crop production. They have been studied to a much lesser extent in horticultural systems, perhaps due in part to the variability in the intensity of horticultural 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.

Objectives

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. Specifically, this project aims to quantify N and C cycling in pools sensitive to management in five farming systems for three years. we are also seeking to contextualize our soil- and plant-based flows within the broader farming systems by using life cycle analytical approaches. In this work, we present preliminary trace gas flux, leaching, and system input:output results from the first year of this project in a subset of these systems.

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Materials and 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. The three systems presented in this work are 1) a pasture-based Extensive Organic system, 2) an Organic High Tunnel and 3) a Conventional system (Fig 1).

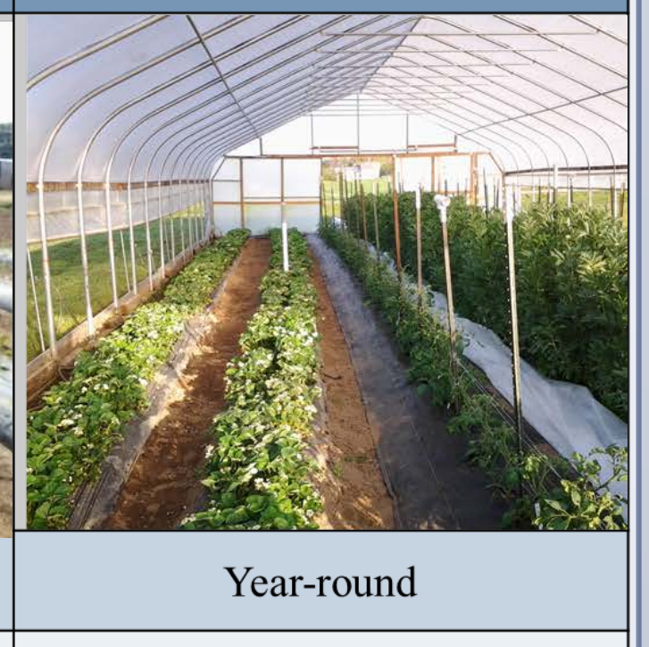
	Extensive Organic	Conventional	Stationary Organic High Tunnel
			
Production	Seasonal*	Seasonal*	Year-round
Fallow Periods	5 year forage-based fallow, with rotational grazing	Annual cover crop once per year	None
Tillage Frequency	None (fallow) -> Intensive semi-annual primary and secondary (horticulture)	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: A subset of the systems in this study representing different level of intensification and parameters for characterizing the intensification gradient.

Mineral N (NO_3^- and NH_4^+) leaching was measured using ion exchange resin lysimeters (after Susfalk and Johnson, 2002) installed at 60 cm depth, replaced every 3 months (Fig 2). Additionally, N mineralization was measured using ion-exchange resin bags placed at 7.5 cm and 22.5 cm depths, replaced monthly, as well as monthly soil sampling at 0-15 cm, 15-30, and 30-50 cm depths.

Fig 2: Ion exchange resin lysimeter used to measure mineral N leaching.

Mineral N samples were analyzed by colorimetric analysis on a microplate reader (BioTek Instruments, Inc, Winooski, VT) after reduction of NO_3^- samples via a cadmium reduction device (ParaTechs Co., Lexington, KY) (Crutchfield & Grove, 2011).

Greenhouse gas emissions (N_2O, NH_3, CO_2, and CH_4) were measured weekly using a FTIR-based field gas analyzer (Fig 3) (Gasmet Technologies, Finland).

Fig 3: Gasmet DX4040 FTIR-based field gas analyzer used to measure trace gas fluxes.

Results

Trace gas flux rates

Preliminary CO_2 and N_2O fluxes measured during the 2014 main growing season (Figs 4 and 5) 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.

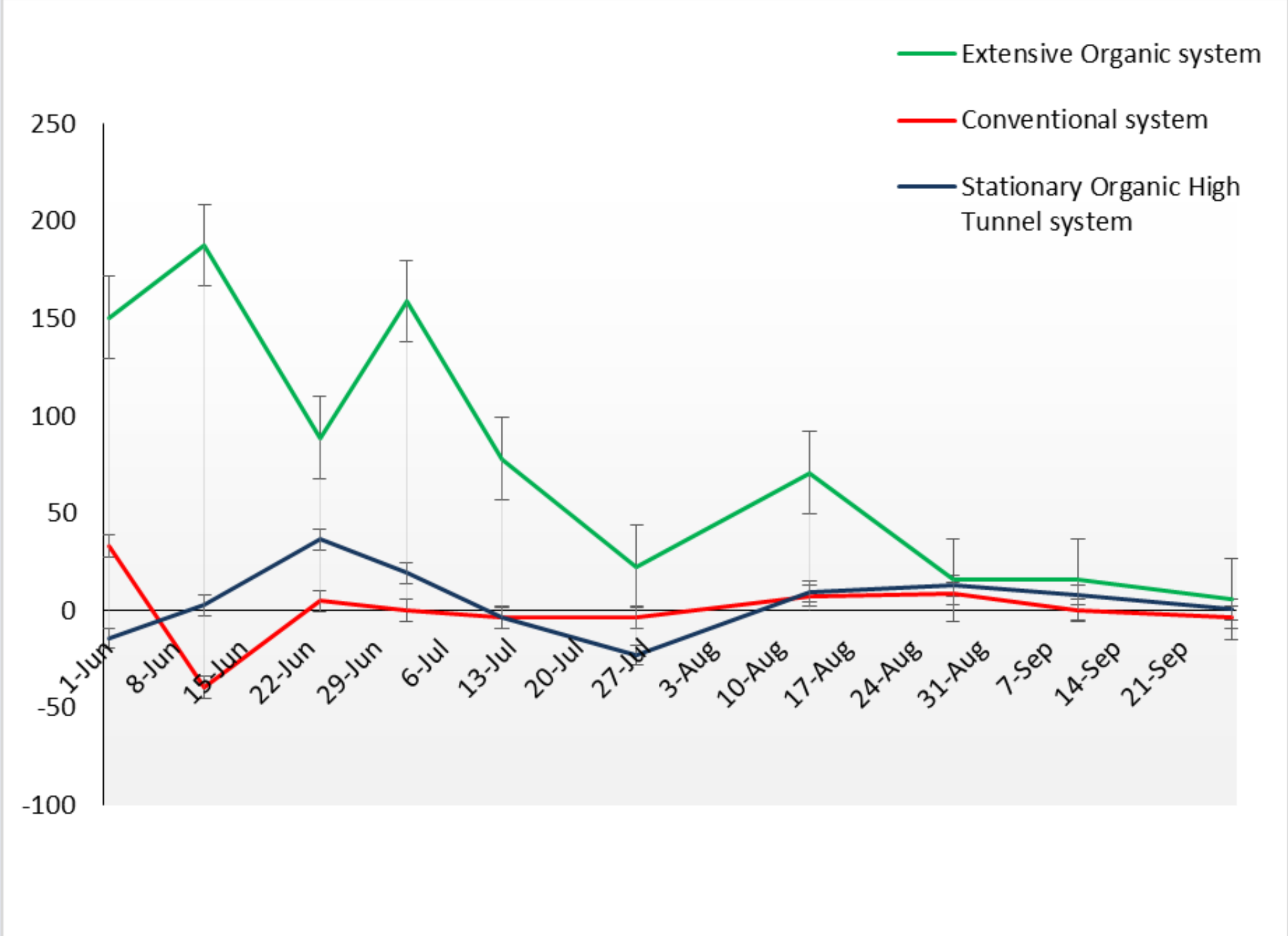


Fig 4: N_2O flux ($\mu g\ m^{-2}\ hr^{-1}$) in three of the study systems during the 2014 main growing season.

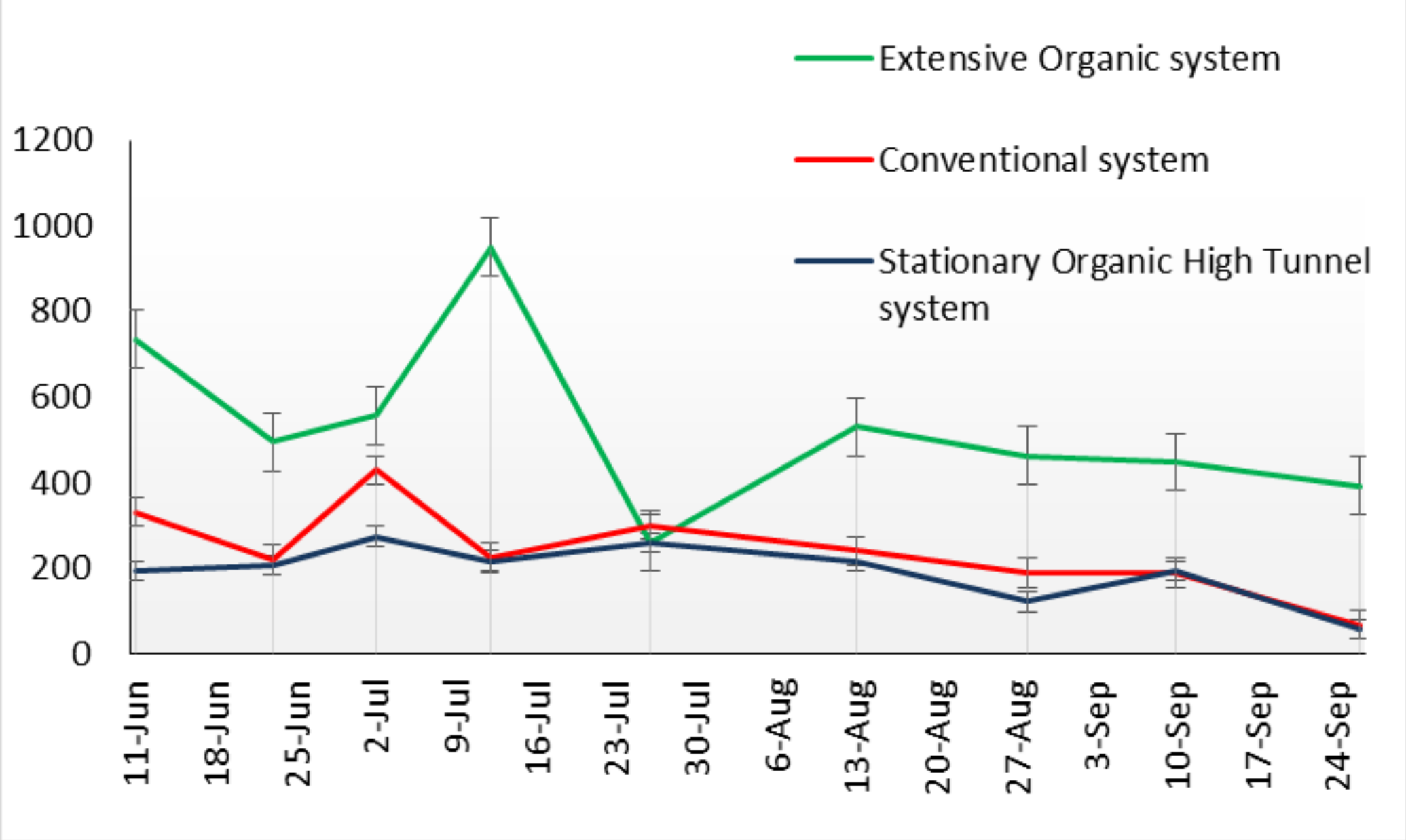


Fig 5: CO_2 flux ($mg\ m^{-2}\ hr^{-1}$) in three of the study systems during the 2014 main growing season.

Nitrogen leaching

Preliminary leaching data indicate the Conventional system may be exhibiting greater mineral N loss rates than the other study systems (Fig 6).

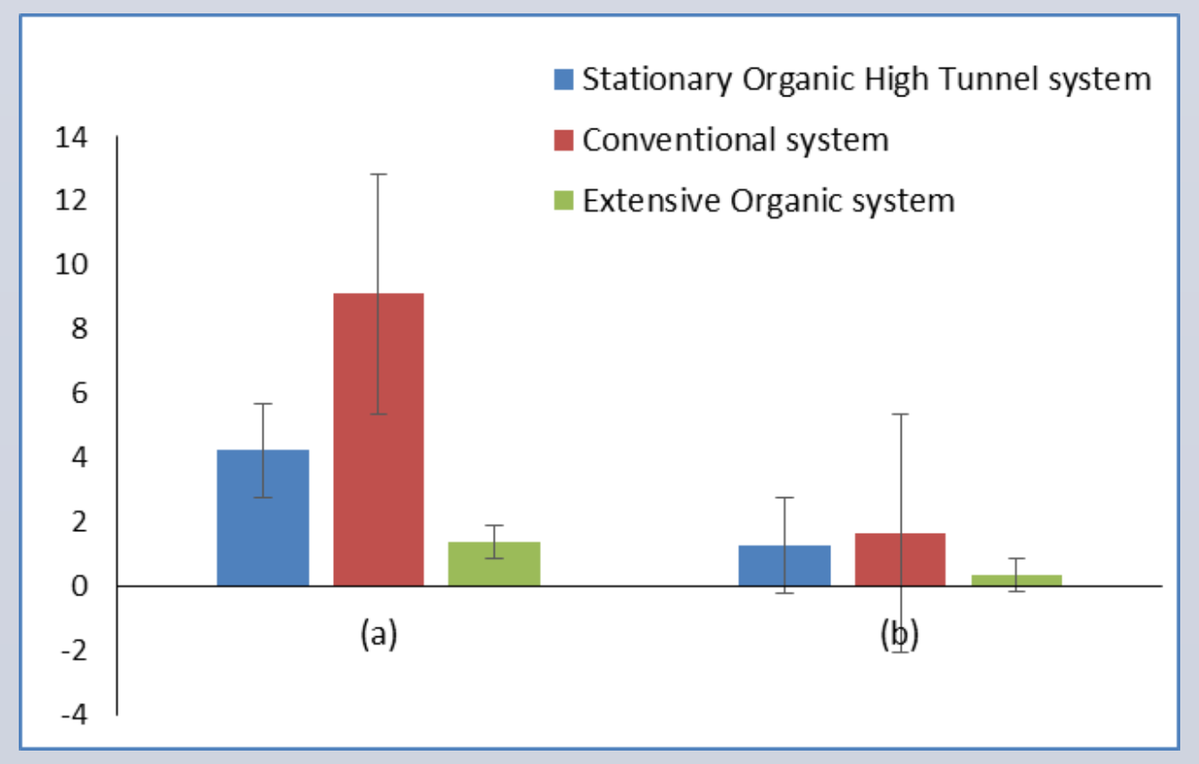


Fig 6: (a) NO_3^- and (b) NH_4^+ leaching loss (ppm per lysimeter) during the first six months of the study.

Whole system energy input:output

Preliminary results for the 2014 calendar year indicate that the Extensive Organic system has a far lower total energy usage per unit output than other systems. At the time of this writing, data were available for the Extensive system and a commercial, mechanized organic system also used in the study (a "Medium Scale Organic" system). The cumulative ratio for the Extensive Organic system is approximately 10 (Fig 7). The cumulative ratio for the Medium Scale Organic system, is approximately 48 (Fig 8).

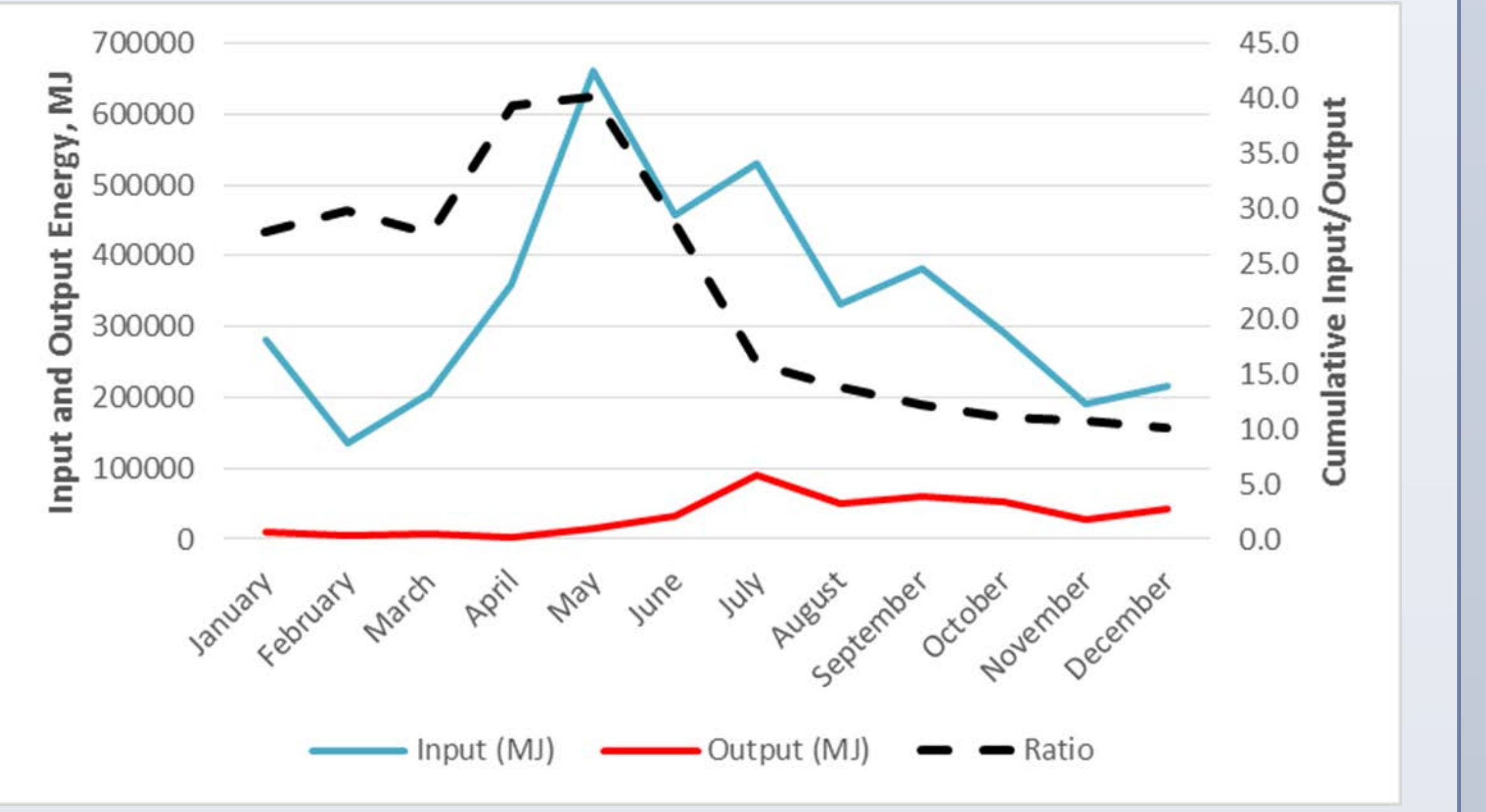


Fig 7: Energy input and output contributions for the Extensive Organic system for 2014.

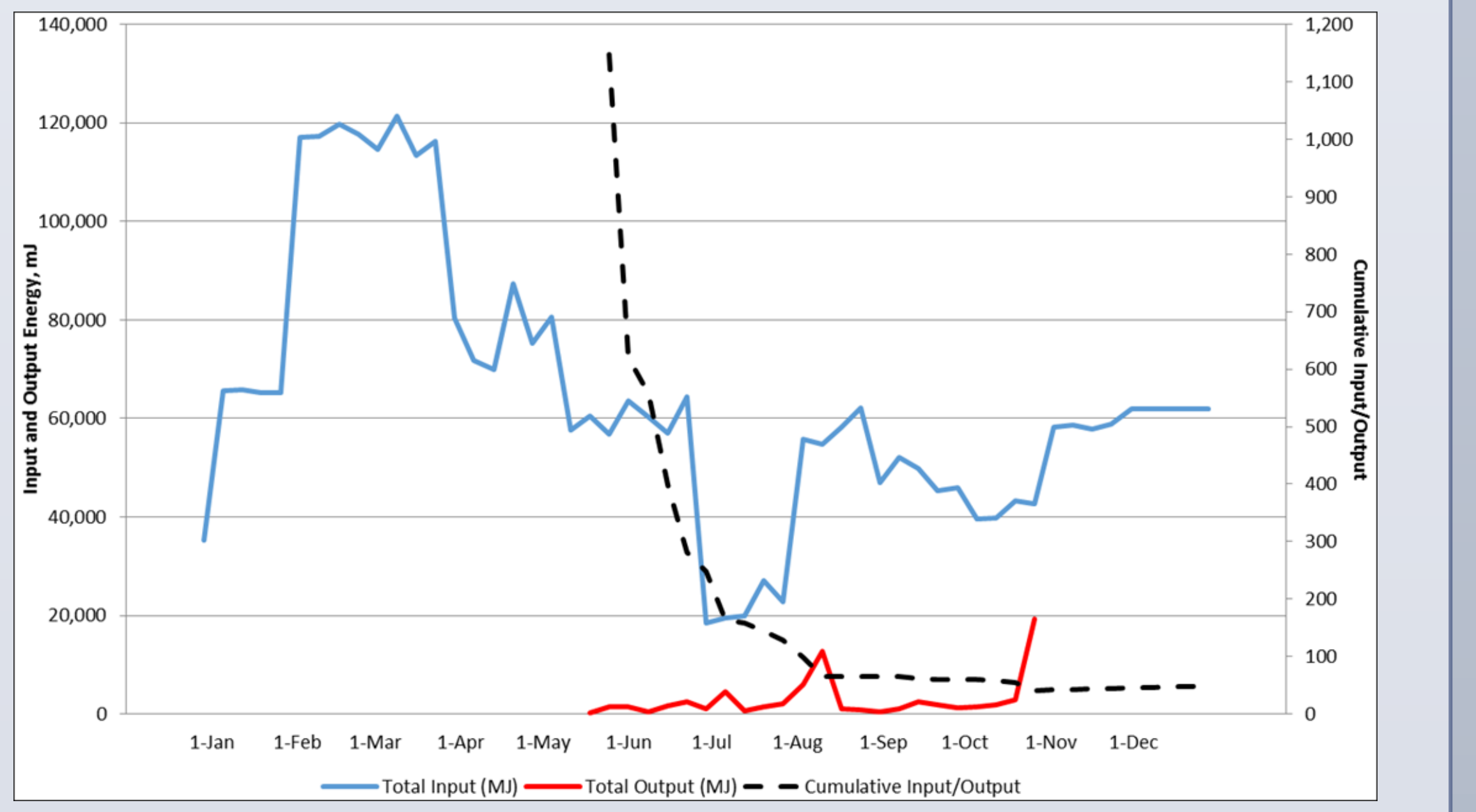


Fig 8: Energy input and output contributions for the Medium Scale Organic system for 2014.

Conclusions

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 two additional years of field data, and include other soil- and plant-based parameters to characterize labile N and C cycling in these systems.

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