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A new lysimeter facility for the study of soil ecosystem services provided by diverse cropping systems

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Introduction

Non-diversified crop rotations such as long-term monoculture production of annual crops, can result in the decline of soil quality, threatening the sustainability of food production systems. Diversifying annual crop rotations is a strategy that mimics natural ecosystems and is postulated to increase agricultural resilience to climate change, soil quality and provision of soil ecosystem services (SES).

There is some evidence that cropping systems with diversified annual rotations (through the inclusion of cover crops, overwintering wheat, and/or alfalfa) can result in higher crop yields and crop N use efficiency [1,2], higher tolerance to drought conditions[1], improved yield stability over time[1], increased productivity per unit area[3], lower requirement for fertilizer and pesticides[2], higher net returns[4], improved SOM and microbial activity[5], and reduced N_2O loss and NO_3^- leaching[6]. However, a comprehensive assessment of mechanisms underlying SES improvements has not been conducted.

Large-weighing soil lysimeters are considered the best alternative for precise water flux and nutrient flux measurements under field conditions, but are costly[7]. Large lysimeters have been used since the 19th century for measuring soil water and solute fluxes[8], but rarely been used in studies which integrate cropping systems, microbial ecology, soil organic matter and greenhouse gas fluxes.

A long-term project using large soil lysimeters was recently initiated to address the following questions: (i) are diverse cropping systems actually beneficial for air and water quality? (ii) what are the trade-offs between soil, water, and air quality upon implementing a diverse cropping rotation, with a focus on carbon and nitrogen cycling? (iii) what is the effect of winter warming on nutrient losses? Here we provide an overview of the approach used, some preliminary results and future plans.

Overview of Facility and Planned Research

The new soil lysimeter infrastructure was installed at the Elora Research Station, University of Guelph, located in Elora (lat. 43o39‘N, long. 80o25‘W, 376 m elevation), Ontario, Canada, in June 2016. It consists of eighteen high precision-weighing soil lysimeters (1 m² x 1.5 m deep; UMS, Germany) fully instrumented for sampling at various depths, 9 of each soil type (Guelph silt loam, 29% sand, 19% clay; Norfolk sand, 90% sand, 5% clay). Each lysimeter was installed in a 3x10 m plot, with 6 lysimeters

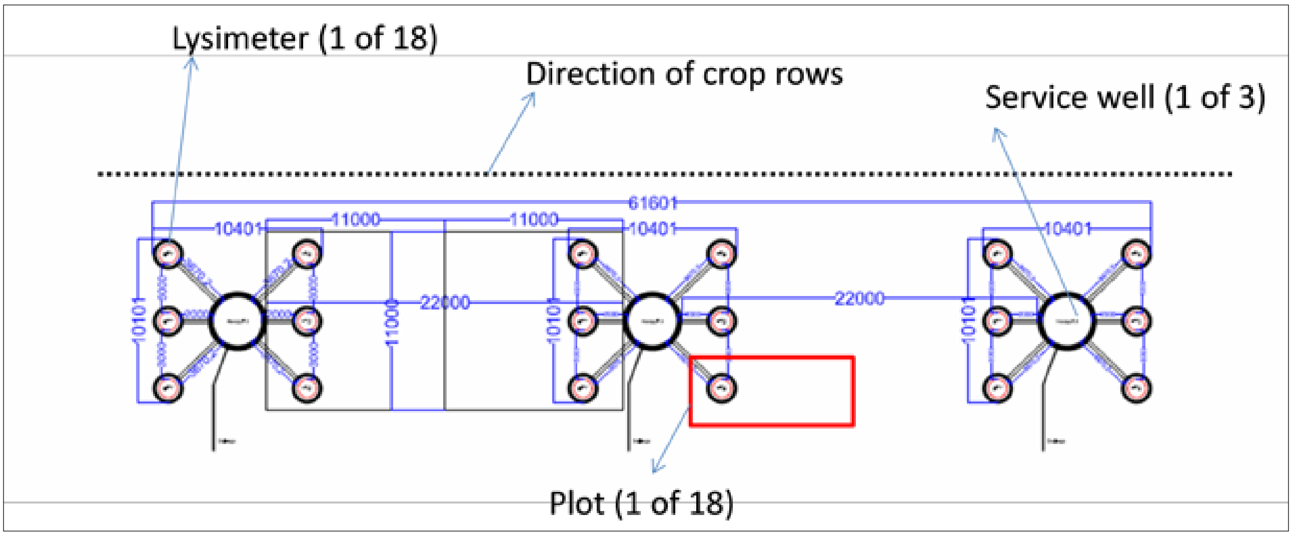

Figure 1: **Schematic of the new lysimeter facility in Elora, Ontario, Canada.**

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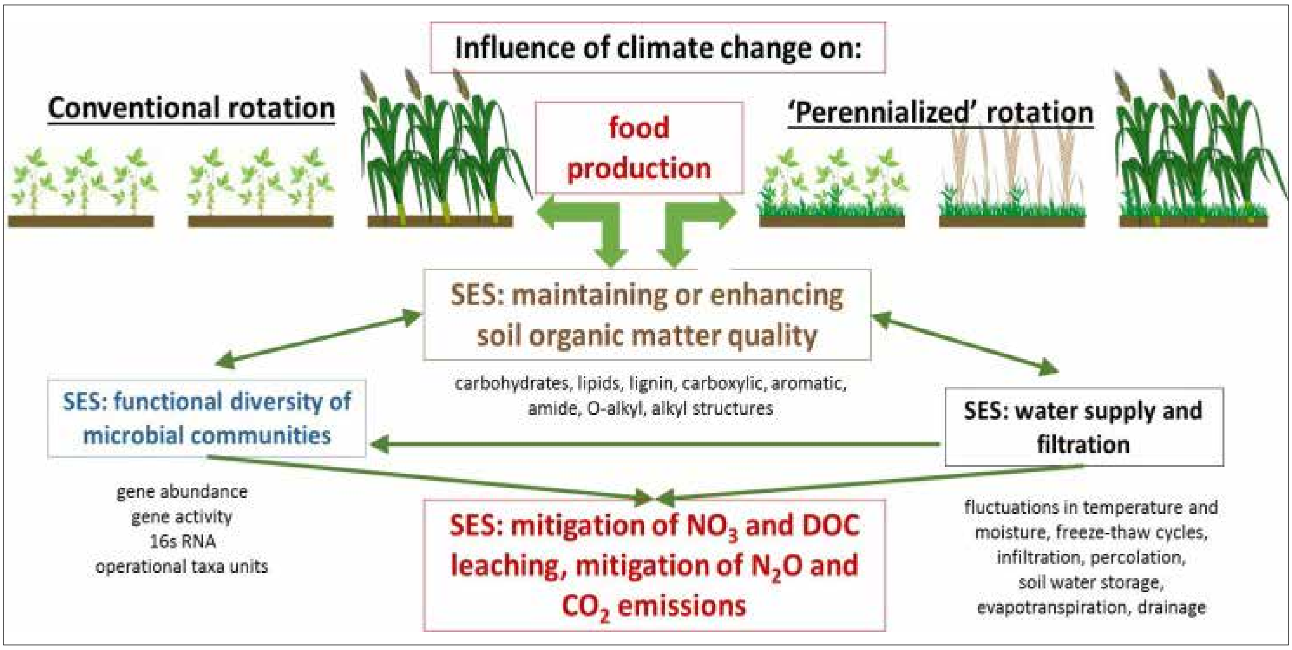

Figure 2. **Mechanisms and relationships which underlie soil ecosystem services (SES) in agroecosystems. This research will aid in (1) adapting agricultural systems to climate change, (2) strengthening water resource sustainability, and (3) contribute to intensifying agriculture in a sustainable manner.**

connected to one service well (total of 3 wells) (*Figure 1*). The area comprising 18 plots was planted with the same crop (soybean) in June 2016 to establish an initial baseline. The following treatments will be implemented with 3 replicates in 2017: 1) conventional (soybean-corn-soybean); 2) "perennialized" (PER) annual crops (spring wheat-corn-soybean with intercropping and cover cropping implemented every year); 3) PER with winter warming. Plots will be managed using no-tillage and recommended practices for this region. In the long-term it is expected that fertilizer management will be adjusted in the PER system to reflect soil N cycling but for the first 3 years we will maintain similar rates, etc. for all treatments.

The lysimeters are instrumented at depths of 5, 10, 30, 60 and 90 cm for measurements of soil water content (TDR probes, Trime), soil matrix potential (T8, UMS; and MPS6, Decagon), soil temperature (Trime, T8 and MPS6), gas lance for manual sampling and automatic CO_2 analysis for 12 depths per service well of 6 lysimeters, soil solution (SIC samplers; manual sampling), lysimeter and drainage tank weight. Each lysimeter has a 20 cm PVC collar fitted with an automatic chamber interfaced with a tunable diode laser trace gas analyzer (TGA200A, Campbell Scientific) for N_2O and CO_2 flux measurements.

This is a long-term facility which will be dedicated to the inter-disciplinary study of SES and the interaction of management and climate change on SES. In addition to the water, C and N budget studied with lysimeters and gas chambers, we will use sophisticated techniques to characterize soil microbial communities and soil organic matter quality (e.g. metagenomics, nuclear magnetic resonance spectroscopy) as well as rely on isotopic tracers and cavity ring-down spectroscopy to better understand processes involved in benefits and trade-offs of water, soil and air quality impacts of diverse cropping systems.

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