Impact of Topsoil Depth and Amendment Application on Soil and Carbon Losses under Simulated Rainfall

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INTRODUCTION

The loss of fertile topsoil is a severe environmental problem in the U.S. Corn Belt region (Pimentel and Burgess, 2013). Satisfying the growing demands for food, feed, fiber, and fuel, necessitates a significant shift in the management of agroecosystems towards sustainable intensification (SI). Soil erosion is a 4-stage process involving the detachment, splash, transport and redistribution, and deposition of soil particles over the landscape (Lal, 2018). Erosion-induced degradation adversely impacts soil health. Adequate quality and topsoil depth are essential to functioning of terrestrial ecosystems (Gregory et al., 2016). Erosion hinders the ability for soil to carry out specific functions due to depletion of the soil organic carbon (SOC) stock and adverse changes in soil physical, chemical, and biological properties. Addressing these growing challenges needs reevaluation of site-specific best management practices (BMPs) to minimize the risks of soil degradation and restore soil health delivery of essential ecosystem services (Olson et al., 2017). Restoring soil health of eroded soils will increase soil's resistance to further erosion and degradation from natural and anthropogenic perturbations and decrease losses incurred (Larney et al., 2016).

RATIONALE

Limited long-term studies quantifying the effects of topsoil depth (TSD) on soil health and alleviation of topsoil loss with amendment application are available for the U.S. Corn Belt region. The overall objective of this study is to assess soil health using specific indicators on two truncated soils in Central Ohio and to evaluate the capacity to restore soil health and resilience through the use of amendments (compost and fertilizers).

Specific objectives:

1. Assess the rate of soil, carbon, and nutrient losses for soils with varying topsoil depths and receiving different amendment application.
2. Assess the effect of moisture content (dry vs. wet) on the losses incurred.

Figure 1. Soil surface after simulated rainfall for soils receiving inorganic N amendment (left) and organic amendment (right).

METHODS

Study Site and Experimental Design:

(1) Waterman Agricultural and Natural Resources Laboratory (Waterman Farm) in Columbus, Ohio

- Plots were established in 1997.
- Crosby silt loam (Fine, mixed, active, mesic Aeric Epiaqualfs).
- The surface profile of this soil has a silt loam texture while the subsurface has silty clay loam to loam texture. The soil is classified as somewhat poorly drained, derived from glacial till, and has a 2-6% slope (USDA-NRCS).
- Maize-soybean cropping rotation.

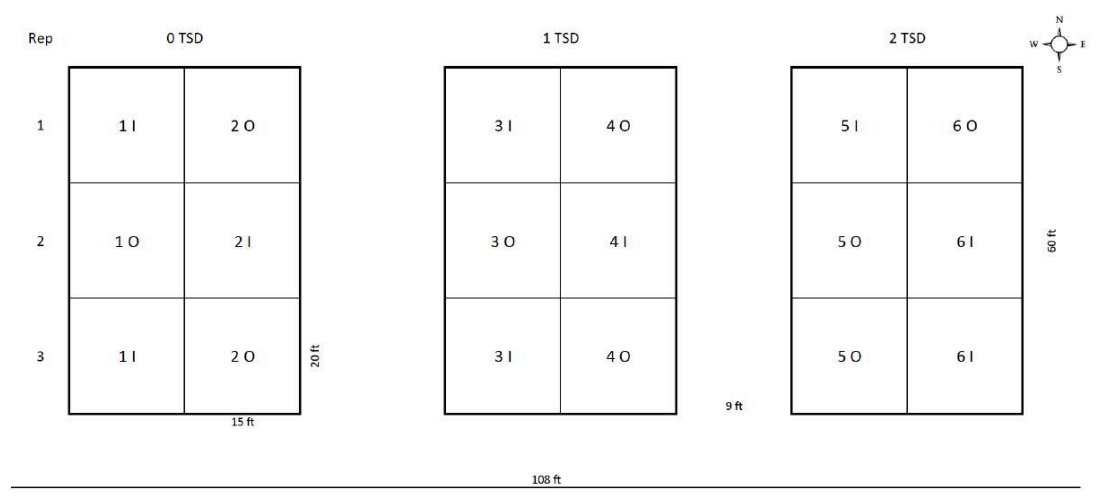

Figure 2. Experimental layout at Waterman Farm (Columbus, OH). Main plots are topsoil depths (0 TSD = 20 cm topsoil removal, 1 TSD = undisturbed, 2 TSD = 20 cm topsoil added. Split plots are amendment application (I = synthetic N fertilizer, O = compost manure.

Table 1. Select soil physical and chemical properties for soils at Waterman Farm for 0-10 cm depth.

Treatment	Bulk Density (g cm^{-3})	Soil pH	Soil Organic C (%)	% Water Stable Aggregates (%)	Mean Weight Diameter (mm)
Topsoil Depth*					
0 TSD	1.29	6.24	3.58	92.9	3.76
1 TSD	1.23	5.98	4.05	96.1	4.45
2 TSD	1.19	5.85	3.48	94.2	3.85
Amendment Type					
N fertilizer	1.38	5.26	2.69	92.8	3.61
Compost Manure	1.09	6.78	4.71	96.1	4.42

*0 TSD = soil removal; 1 TSD = undisturbed; 2 TSD = soil addition

Methodology:

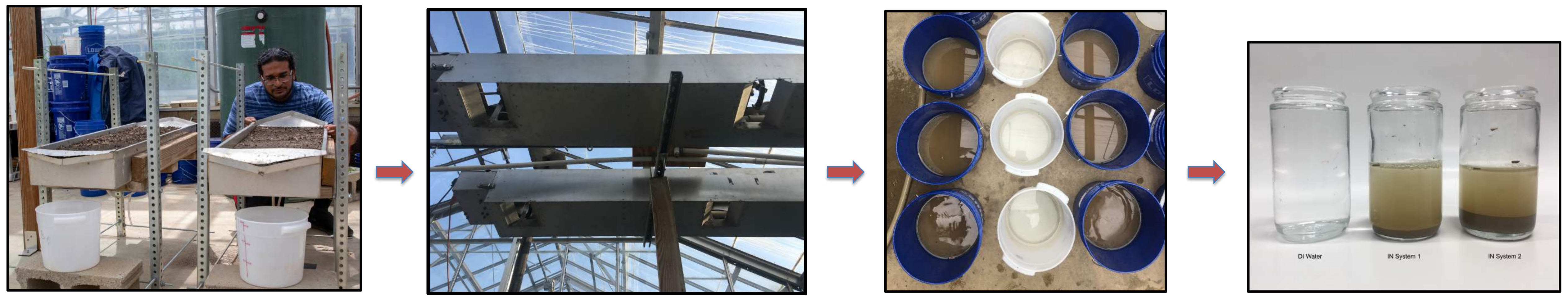

Figure 3. Experimental Procedure for determining soil and carbon losses under simulated rainfall. (A) Preparation of soil flumes for study. (B) Programmable rainfall simulators used for study. Rainfall simulators are installed 2.5 m above soil flumes. Simulated rainfall was applied at a rate of 90 mm hr^{-1}. (C) Surface runoff, sediment loss, and percolation was collected at 5-minute intervals for duration of experiment. (D) Quantification of the volume of surface runoff and percolation collected and mass of sediment loss incurred.

PRELIMINARY RESULTS

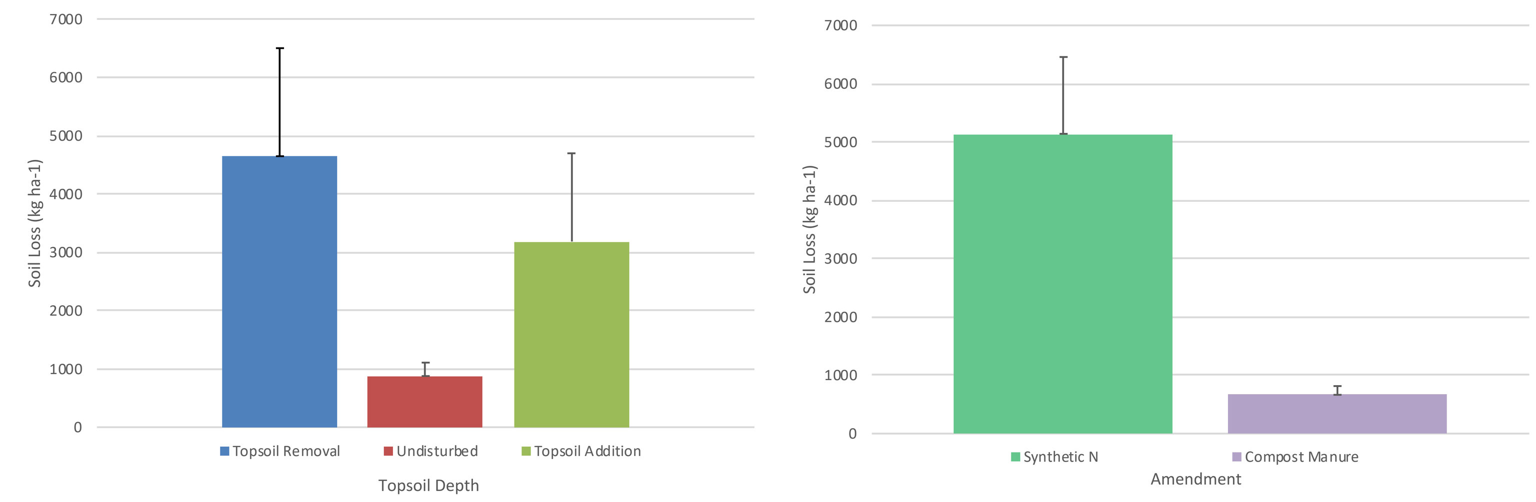

Figure 4. Soil loss under varying topsoil depths (left) and amendment applications (right).

- Soil loss followed a trend where 0 TSD (topsoil removal) > 2 TSD (topsoil addition) > 1 TSD (undisturbed).
- Soil loss was greatest in the plots receiving an inorganic amendment vs those receiving an organic amendment.

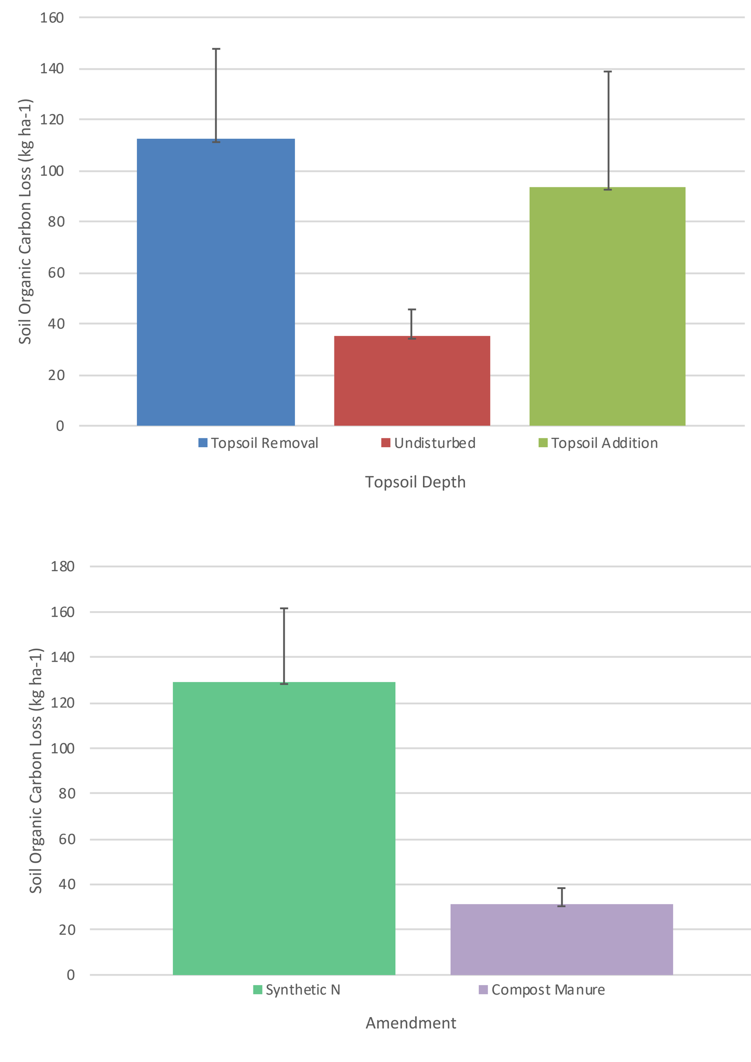

Figure 5. Soil organic carbon losses under varying topsoil depths (top) and amendment applications (bottom).

- SOC loss followed a trend where 0 TSD (topsoil removal) > 2 TSD (topsoil addition) > 1 TSD (undisturbed).
- SOC loss was greatest in the plots receiving an inorganic amendment vs those receiving an organic amendment.

CONCLUSIONS

- Soils that were undisturbed (original topsoil depth) incurred fewer soil and carbon losses.
- Soils amended with compost manure experienced lower overall losses then those amended with only synthetic N.
- Soils with lower SOC content and lower % water stable aggregates had greater soil and carbon losses.

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