Do erosional and depositional processes in agricultural landscapes sequester carbon?

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Abstract

There are many reasons for reducing erosion in agricultural landscapes, but there has yet to be a definitive answer as to whether carbon sequestration is among them. Previous studies have shown that agricultural erosion is neither a sink nor source of soil organic carbon (SOC) categorically; rather, it may vary between the two depending on field conditions and management practices. This study sought to better understand the effects of soil movement mechanisms on SOC by combining measurements of SOC and ^{137}Cs (produced during atmospheric testing of nuclear bombs in the 1960s). As a fallout radioisotope, ^{137}Cs becomes strongly adsorbed to surface soil particles and functions as a conservative tracer for soil movement over the past approximately 50 years. For this study, soil samples were collected from croplands and grasslands in southeastern Minnesota. Results show a ^{137}Cs/SOC ratio in cropland soils that is consistently less than the observed ratio for grasslands, suggesting that despite erosional tendencies, cropland soils are preferential SOC sinks. Overall, the data imply that SOC is effectively sequestered via burial due to erosional and depositional processes, rather than physically decomposed to be lost as CO_2.

Objective

Van Oost *et al.* (2007) outline the three major mechanisms that have the ability to alter the SOC flux between soil and atmosphere: 1) replacement of SOC with organic inputs at the site of erosion, 2) burial of SOC wherein decomposition is inhibited, and 3) quickened decomposition of SOC during detachment and transport phases of erosion (Fig. 1).

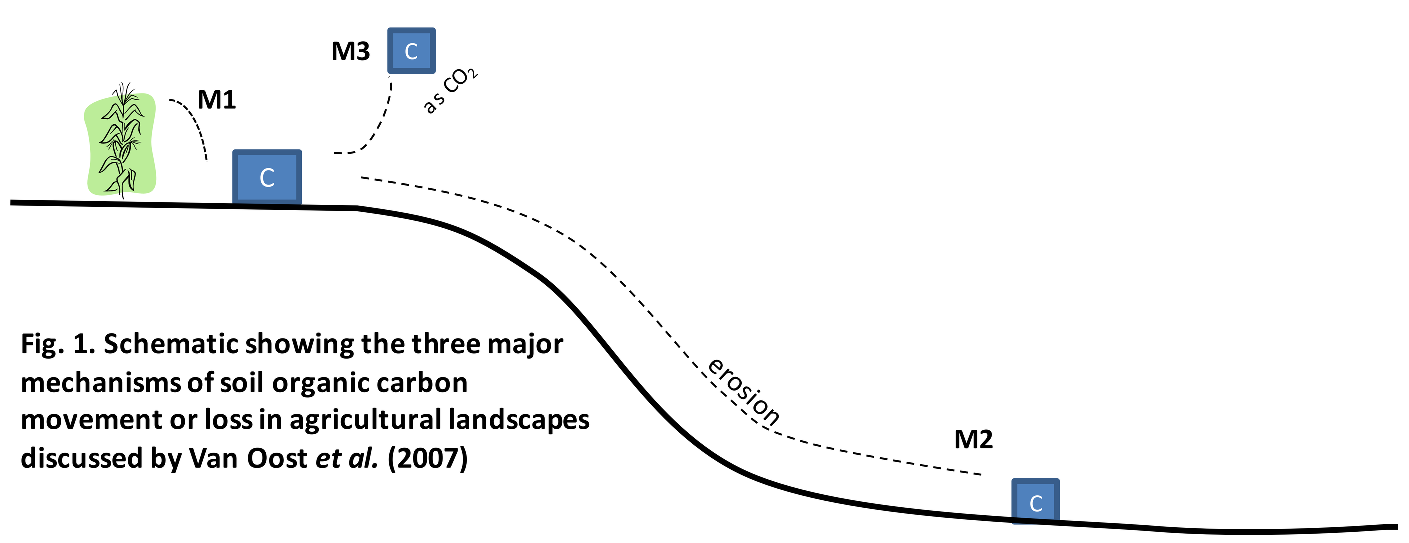


Fig. 1. Schematic showing the three major mechanisms of soil organic carbon movement or loss in agricultural landscapes discussed by Van Oost *et al.* (2007)

In a study on undisturbed Japanese forest soils, Takenaka *et al.* (1998) found that the spatial distributions of ^{137}Cs and SOC were strongly correlated, despite the fact that they result from different processes (Fig. 2).

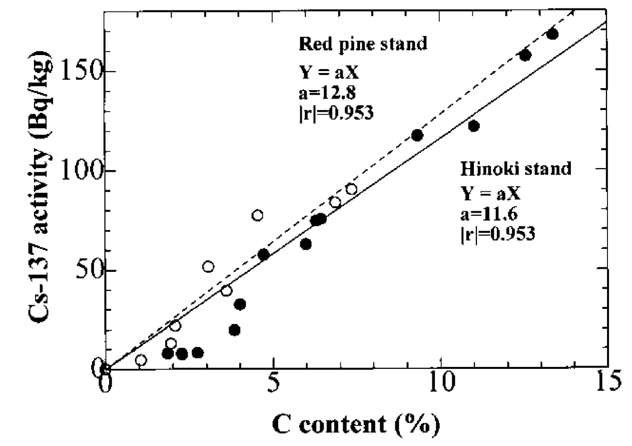


Fig. 2. Takenaka *et al.* (1998)

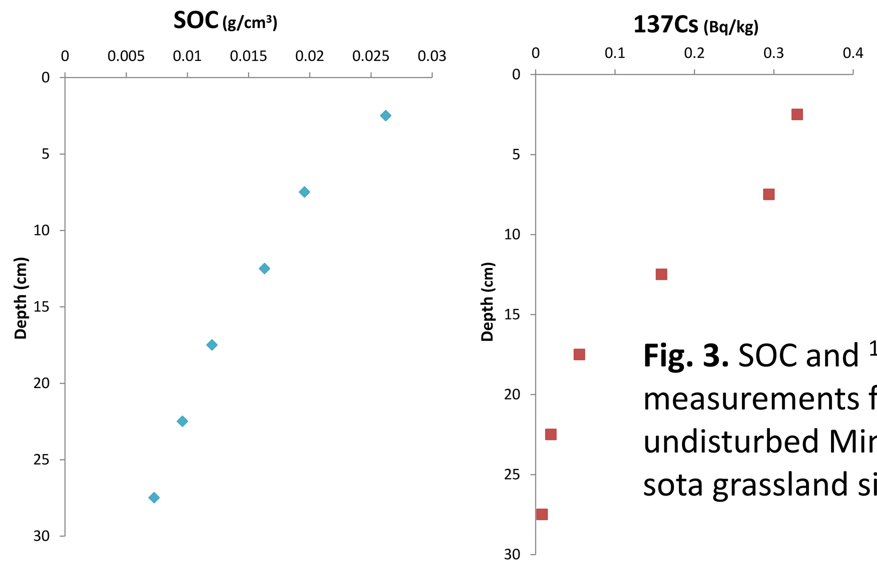


Fig. 3. SOC and ^{137}Cs measurements for an undisturbed Minnesota grassland site

We observed similar distributions of SOC and ^{137}Cs in Minnesota grassland soils (Fig. 3), and our objective was to determine whether this relationship holds true in agricultural soils.

Hypotheses

The goal of this project was to determine whether the relationship between SOC and ^{137}Cs shown by Takenaka *et al.* (1998) holds in Minnesota agricultural landscapes (when compared to grassland reference sites), thereby testing whether SOC in erosional settings is lost via decomposition or sequestered via deposition (Fig. 4).

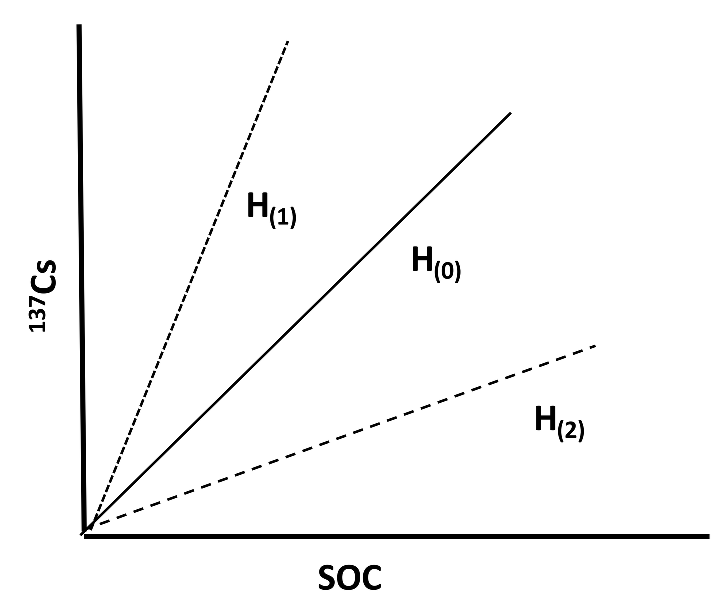


Fig. 4. Hypotheses representing possible outcomes

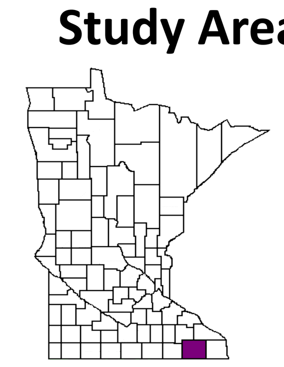
$H_{(0)}$: expected ratio for grassland sites; SOC is correlated with ^{137}Cs measurements, although the distributions of SOC and ^{137}Cs result from different processes

$H_{(1)}$: SOC diminishes relative to ^{137}Cs; suggestive of mechanism 3 presented by Van Oost *et al.* (2007) where SOC decomposition is hastened via erosion and lost as CO_2

$H_{(2)}$: SOC increases relative to ^{137}Cs; suggestive of mechanisms 1 and/or 2 presented by Van Oost *et al.* (2007) where SOC is replaced with organic inputs or preferentially buried via erosion

Methods

Study Area



Samples were collected from multiple agricultural and grassland sites throughout Fillmore County in southeastern Minnesota in the summer of 2010. Agricultural soil samples were collected from two private fields (with landowner permission). Grassland soils were collected from William Pease Wildlife Management Area.

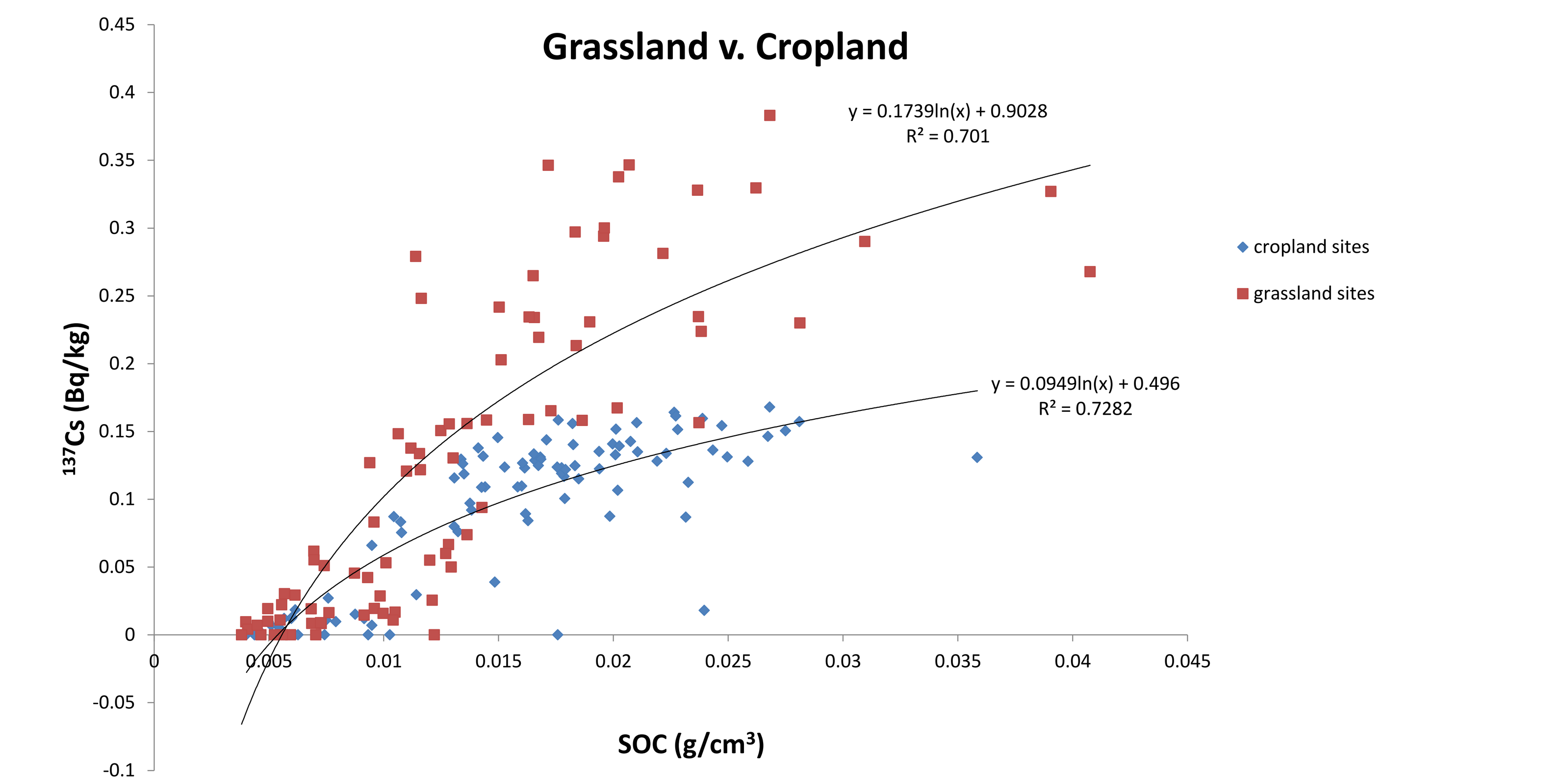
Field

Samples were collected in 5 to 10 cm increments to a depth of 50 cm below the soil surface. Four more samples were taken in 25 cm increments using a hammer auger, to a total depth of 150 cm.

Laboratory

Samples were dried, ground, and sieved according to standard protocols. SOC analysis was conducted via high temperature combustion with an Elementar Vario MAX analyzer. ^{137}Cs analysis was conducted with a Broad Energy Germanium Detector (Canberra) housed in the Department of Soil, Water, and Climate (pictured left). UTM coordinates for each sample (previously recorded) were corresponded with LiDAR digital elevation models to align landscape positions and terrain attributes with SOC and ^{137}Cs distributions.

Results



The data display a ^{137}Cs/SOC correlation similar to the relationship found by Takenaka *et al.* (1998), although both datasets are better described by a logarithmic trend (as opposed to a linear one). Both trends are positive and fairly strong, but less tightly correlated than the data presented by Takenaka *et al.* (1998). Undisturbed grassland sites aligned with our expectations in accordance with the literature and $H_{(0)}$. The ^{137}Cs/SOC ratio for cropland soils falls consistently below the grassland soil ratio, which aligns with $H_{(2)}$. This suggests that SOC is either replaced by organic inputs at erosional sites or effectively sequestered via burial due to redistributive soil movement processes, rather than physically decomposed to be lost as CO_2. Overall, the data imply that despite erosional tendencies, agricultural soils are preferential SOC sinks at these sites.

Ideas for Further Study

- How will separating sites by their landscape positions reflect expected trends in ^{137}Cs/SOC data?
- Quantification of total ^{137}Cs inventory for sampling sites in order to assess whether each site has served as a collection site for eroded soil from other landscape positions or is a net contributor of soil to other locations.
- Use of other radioisotopes to measure soil movement, particularly ^{210}Pb.

References

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