Soil Carbon Changes in Cultivated Land Converted to Grasses in South-Central Saskatchewan

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Abstract

Soils play an important role in the carbon cycle. Under natural conditions, soil organic carbon forms an equilibrium with the environment. Disruption to this equilibrium can transform the soils into either a source or a sink for atmospheric CO_2. Mensah (2000) found in the Black and Gray soil zone that the conversion of marginal cultivated land to grassland resulted in an increase in soil organic carbon of 0.6 Mg C ha^{-1} yr^{-1} to 1.2 Mg ha^{-1} yr^{-1} (0-15 cm depth) across the landscape over a ten year period. However, little information is available on carbon sequestration rates from grassland restoration in the Brown and Dark Brown soil zones of the southern Prairies. The Missouri Coteau region in southern Saskatchewan is comprised predominantly of Brown and Dark Brown soils that, due to steep topography and stoniness, pose limitations for production of annual crops. The effect of conversion to grassland on the forms and distribution of soil carbon was examined using side-by-side paired cultivated and grassland catenae that had been in a grass seed-down for about eight years. Total soil organic carbon in the 0-15 cm depth of the shoulder, midslope and footslope positions were measured. The shoulder positions showed the greatest increase in soil organic carbon from grass seed-down, with an average apparent increase in soil carbon of 1.62 Mg ha^{-1} yr^{-1}. Carbon distribution with depth was found to be dependant upon the cropping history of the cultivated equivalent as well as the parent material. Greatest apparent carbon gains were observed when the cultivated comparable was in a cereal-fallow rotation and the lowest gain from grass seed-down occurred when the cultivated comparable contained a legume in rotation.

Introduction

Soils play an important role as sources and sinks of carbon in the environment. In native uncultivated soils, soil carbon is in equilibrium with the environment where the amount sequestered per year is equal to the amount given off by respiration processes. If cultivated, this equilibrium is disrupted resulting in losses of soil carbon until a new equilibrium is reached. Conversion back to grassland alters the equilibrium again and carbon can be sequestered (Batjes, 1998).

Objective

To determine changes in soil carbon storage in a hummocky landscape in south central Saskatchewan (Missouri Coteau region) as affected by grass seed-down of cultivated land for eight years.

Literature Review

Factors affecting carbon dynamics

•Distributions of soil organic carbon, SOC, on a landscape scale are usually distinct. In agricultural soils, higher organic matter concentrations usually occur in depressional areas where there is sufficient soil moisture and nutrients to promote growth (Pennock and Van Kessel, 1997).

•Texture plays an important role in the formation of aggregates and the soils ability to supply nutrients. Smith et al. (1997) found that more carbon was stored in fine textured soils. Higher productivity, together with the ability of clays to stabilize and retain more organic matter, leads to higher rates of organic carbon sequestration (Gregorich et al., 1994).

•Vegetation plays an important role in the environment. Vegetation will lower the energy and velocity of moving water, resulting in less erosion. On an agricultural field with sparse cover, vegetation density may not be sufficient to slow the water, resulting in significant amounts of erosion (Stoskoph, 1981).

•Management practices influence the amount of carbon in the soil. Cultivation (Salinas-Garcia et al., 1997, Follett and Peterson, 1988) and crop type and rotation influences the amounts of inputs into the system (Janzen et al, 1997). The practice of summer fallowing reduces carbon inputs into the system.

Soil organic carbon and the conversion from cultivation to grassland systems.

• The conversion of grassland to agriculture results in significant losses of soil organic carbon. The converse of this process, the conversion of cultivated land to grassland, was reported to result in an average increase of SOC varying from 0.6 Mg ha^{-1} yr^{-1} to 1.2 Mg ha^{-1} yr^{-1} in the Black and Gray soil zones in east-central Saskatchewan (Mensah, 2000). This increase varied across the landscape with the shoulder positions showing the highest response.

Materials and Methods

The Missouri Coteau region in southern Saskatchewan is comprised predominantly of Brown and Dark Brown soils that, due to steep topography and stoniness, pose limitations for production of annual crops. The effect of conversion to grassland on the forms and distribution of soil carbon was examined using side-by-side paired cultivated and grassland catena that had been in a grass seed-down for about eight years. Total soil and light fraction organic carbon in the 0-15 cm depth of the shoulder, midslope and footslope positions were measured.

Deep (0-60 cm) samples were taken in 15 cm increments from the wetland fringe areas from catena sites on the Missouri Coteau and were analyzed for organic carbon.

Results and Discussion

Although four sites were analyzed in the research project, only two of the sites, Vermillion and Mackow, are discussed in detail here. The other two sites showed similar patterns.

Vermillion: Catena Soil Carbon

A strong positive response in soil organic carbon amounts (0-15cm) to grass seed-down was shown at the Vermillion site (Figure 1). Each landscape position contains a higher amount of soil organic carbon in the grassland restoration than in the cultivated (cereal cropping) equivalent. This increase is attributed to the increase in root and residue carbon inputs in the grassland, decreased erosion, and lack of carbon removed by harvesting.

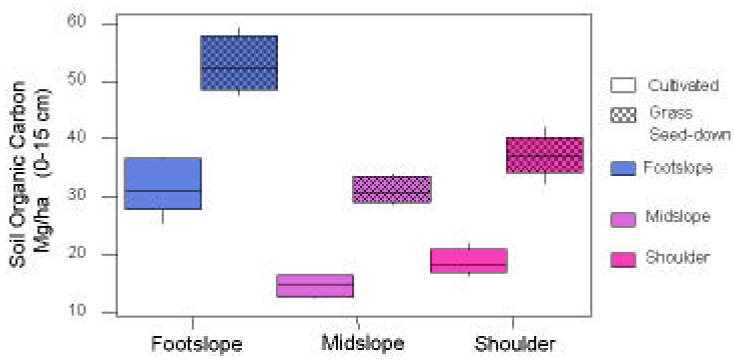

Figure 1. Catena soil carbon distribution

Vermillion: Soil Carbon at Depth

Soil carbon changes in the wetland fringe area (next to slough) were examined in 15 cm depth increments to 60 cm (Figure 2). There was a significant increase ($p < 0.01$) at all depths due to the conversion of the cultivated land to grassland. In the wetland fringe, a dense growth of deep rooted grasses and forbs in the seed-down would add appreciable amounts of carbon to the sub-soil as well as the surface layers.

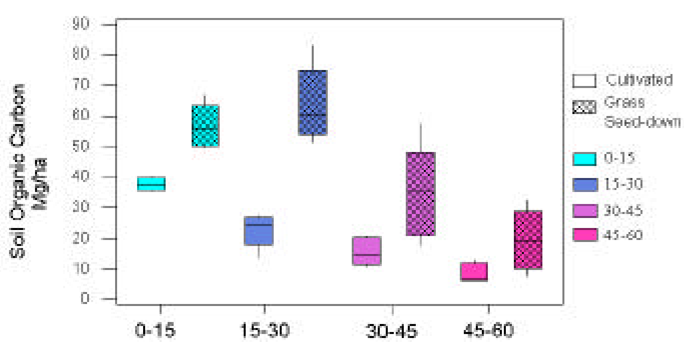

Figure 2: Vermillion soil carbon distribution with depth

Mackow: Soil Carbon Distributions

At the Mackow site, a response atypical to that of the other three sites was observed with the cultivated equivalent having higher amounts of soil organic carbon at depth (Figure 3). The cultivated equivalent of this paired site was a clover – wheat rotation. Carbon additions to the sub-soil may be higher with the clover, owing to its deep rooted nature.

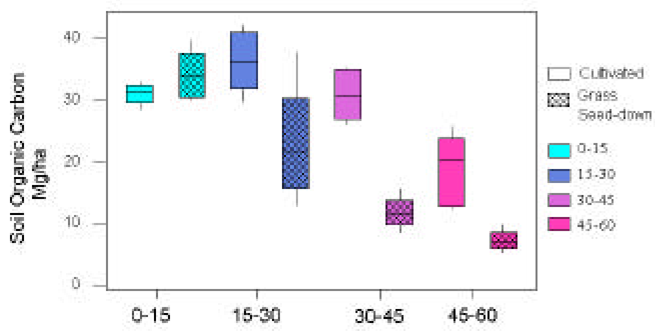

Figure 3. Mackow soil carbon distribution with depth

Summary of Results

Overall, eight years of grass seed-down increased organic carbon stores in the soil as compared to cultivated cereal based equivalents in the Missouri Coteau region. Responses in the surface 0 – 15 cm depth were greatest on the shoulders. Amounts sequestered vary from site to site and apparent gains will depend on the management system used in the cultivated system. If the cultivated system has a forage as part of the rotation, as at the Mackow site, the apparent gains from conversion to grasses are likely to be diminished.

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