Conversion of Annual Cropped Lands to Grasses: Effect on Soil Carbon

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Introduction

Concern over the impact of greenhouse gases (GHG) on global climatic change, resulted in a landmark agreement in Kyoto, Japan in December 1997, where the developed countries of the world agreed to cap their greenhouse gas emissions to predetermined levels by 2010. The three most important GHGs are CO_2, CH_4 and N_2O.

CO_2 is produced when carbon-containing compounds are oxidized. Most of the C stored in agroecosystems occurs in soils. Agricultural practices change the amount of carbon stored in soils when the balance of inputs and outputs are altered. Therefore, soils are one of the ecosystem components that can play a key role in the global C budget due to its role as a net sink or source of CO_2**.**

Land use approaches that will enhance CO_2 incorporation into biomass or soil C reserves, may probably lead to a substantial and sustainable reduction in GHG emissions. The objectives of this study were to investigate land use systems that would be capable of storing more C in the form of plant residue and soil organic carbon for CO_2 mitigation. We attempted to identify factors that can affect C storage; including plant type (forage vs native), slope position, soil climatic zone, and land use management. Indicators measured included soil organic carbon (SOC) and its component light fraction (labile) organic carbon (LFOC).

The study question: *Does reseeding to perennial forages on previously annually cropped land or reversion of cropped land to native vegetation produce a measurable increase in soil organic carbon over a 5-10 y period?*

Materials and Methods

Methods

Stratified randomly sampled soil cores (Completely Randomized Design) were taken using 10cm diameter PVC pipes of 15cm length. Five cores were taken at random over an area of $25m^2$ side-by-side at different slope positions on individual toposequences with different management treatments: Cultivated versus Seed-down to forage mixes.

Cores were sectioned into 0-5, 5-10, and 10-15 cm depth increments and air-dried at 30°C for field bulk density determination. The soils were characterized with respect to pH (1:2 soil:water extract), and electrical conductivity (EC), using a Horiba ES-12 conductivity meter. Soil organic carbon SOC was determined from subsamples, ground to pass 2mm sieve, with a LECO carbon determinator set at 840°C. Light fraction organic carbon (LFOC), the labile pool of soil organic matter (SOM) was obtained by the method of flotation of light (recent) debris in 25g of soil in NaI (1.7 gcm-3), dried at 60 °C, and LFOC determined using LECO carbon determinator.

Sites

Samples were taken at 6 sites at the transition between Dark Brown and thin Black Soil Zones in Ducks Unlimited dense nesting covers (DNCs) around Meacham and Dana (N52° 07’, E105° 45’and N52° 20’, E105° 54’) respectively. The soils are loam and clay loam mixtures of Oxbow, Weyburn and Elstow Associations., with pH ranging from 6.7-8.9, with the generally higher pHs at upper slope positions. EC ranged from 0.1mS cm^{-1} in upper slopes to 3.5 mS cm^{-1} at some lower slope positions. The cultivated treatment portions of the toposequences at the sites consisted of continuously cropped and fallow rotations such as Wheat-Wheat-Canola-Pulse and Wheat-Wheat-F-Canola, maintained for the last 15-20 years, whereas the seed-down portions consisted of species mixes of wheatgrasses (*Agropyron* spp.) and alfalfa seeded with a zero-till drill, 5-12 years ago. One of the sites was a comparison of a grazed native pasture with cultivated land. Slopes of the toposequences ranged from 2% to 16%.

Data Analysis

Data was analyzed with MINITAB Statistical software using a two-sample t-test assuming unequal variances, since a normality test (Anderson-Darling) indicated unequal variances among treatments.

Organic carbon status (Mg ha-1) was determined by the equivalent mass method (Ellert and Bettany, 1995), with higher mean bulk density soils used as reference unit masses to compare an equivalent unit masses of soils with lower mean bulk density. LFOC was also determined in units of Mg ha^{-1}.

1. Soil organic carbon in cultivated and seed-down treatments at different slope positions in 6 side- by-side toposequence comparisons in the Meacham-Dana area.

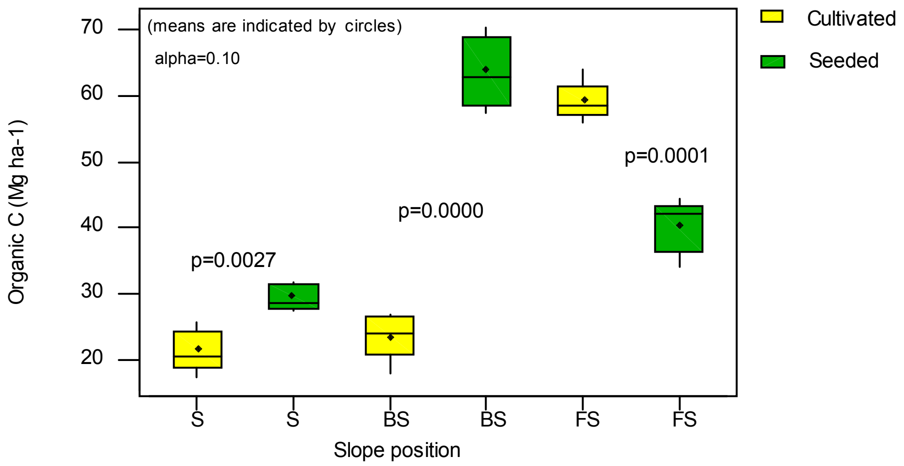

Fig. 1 Boxplots of mean total organic C (0-15 cm depth) at slope positions between treatments. Fontaine. Site #1-Dana Hills

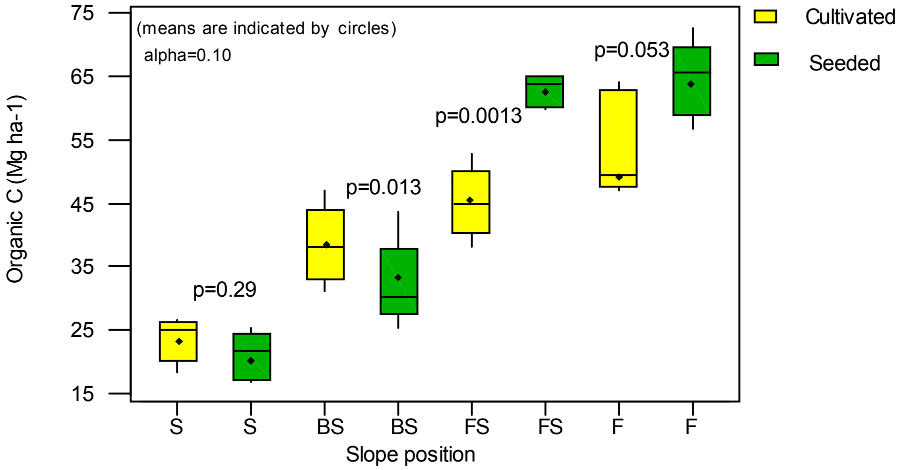

Fig. 2 Boxplots of mean total organic C (0-15 cm depth) at various slope positions between treatments. Gayowski. Site #2 - Dana Hills

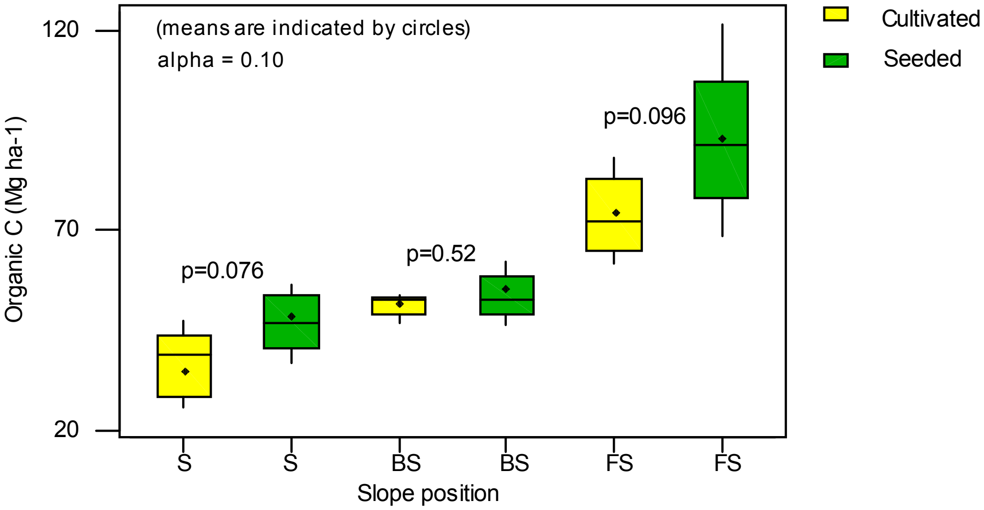

Fig.3 Boxplots of mean total organic C (0-15 cm depth) at slope positions between treatments. Hanuschak. Site #3- Meacham

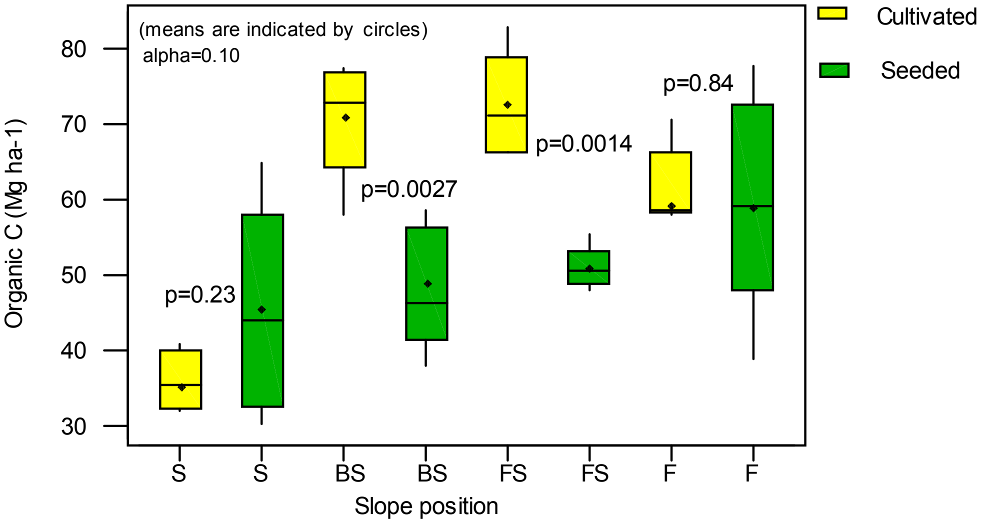

Fig. 4 Boxplots of mean total organic C (0-15 cm depth) at slope positions between treatments. LeBlanc. Site #4 - Meacham

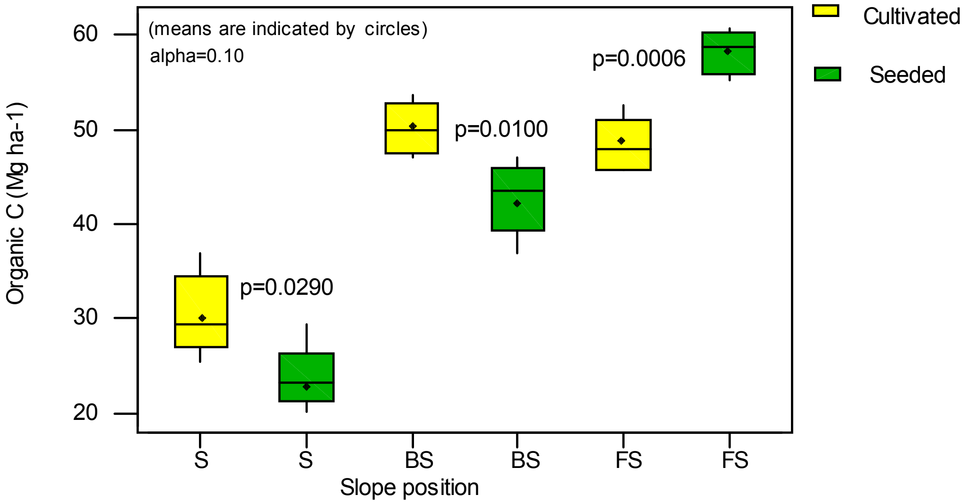

Fig. 5 Boxplots of mean total organic C (0-15 cm depth) at slope positions between treatments. Totzke. Site #5 - Dana Hills

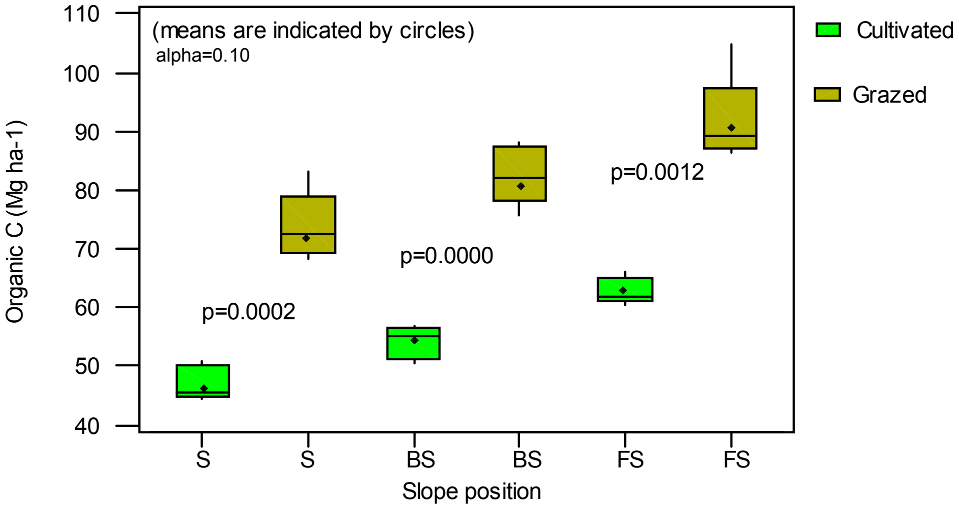

Fig. 6 Boxplots of organic C (0-15 cm depth) at slope positions between treatments. Sopatyk. Site #6 - Meacham

S: shoulder position, BS: backslope position, FS: footslope position, F: wetland fringe

2. Light fraction organic carbon (LFOC)

Mean LFOC (Mg ha^{-1}) results measured in the treatments are indicated in table.1

Site	Cultivated (LFOC Mg ha^{-1})	Seed-down (LFOC Mg ha^{-1})	p-value
1	1.493 ± 0.38	2.459 ± 0.52	0.23
2	1.245 ± 0.32	1.856 ± 0.22	0.18
3	1.275 ± 0.21	2.462 ± 0.54	0.18
4	2.030 ± 0.44	2.506 ± 0.33	0.42
5	1.640 ± 0.08	4.350 ± 1.30	0.18
6	0.797 ± 0.12	1.227 ± 0.08	0.06

Table. 1 Mean LFOC measured at 0-5cm depth only, at different slope positions between treatments at the six sites. $p \leq 0.1$ for significant differences to be detected.

Discussion

SOC status at the time of measurement indicated an impact of the grass seed-down on SOC varied depending on sites and slope positions as indicated in figs 1, 2, 3, 5 and 6. At some sites grass seed-down increased SOC (0-15cm) throughout the landscape i.e. fig. 3, while in others, there was no significant difference or a lower SOC status, i.e. fig. 4. However, because SOC build-up depends on a continuum of decomposition rates of plant residues, especially with respect to LFOC, a lower SOC status, may not imply a decrease due to grass seed-down. LFOC was consistently higher in seed-down in the surface soil (table 1) and LFOC is the precursor to humus.

Overall, the results indicate that SOC responded to grass seed-down. Especially important are the higher SOC content of shoulder positions, where the horizon may be relatively thin, with low productivity, as a consequence of erosion. The shoulder position of the seed-down in Fig. 4, for example, indicated a higher build-up of SOC, although it was not significantly different from that of the cultivated treatment. However, the higher SOC in the cultivated backslope and footslope may be related to the continuous cropping and high residue return at this particular site for the past 15 y. Significantly higher SOC at Site 6, (fig. 6) in the grazed pasture, compared to the cultivated equivalent, may be attributed to the fact that the pasture is native and never cultivated. Site 1 was the only site that showed significantly lower SOC in the footslopes. Sites 2, 3, and 5 showed significantly higher SOC in the seed-down footslopes. More moisture in footslopes may enable more rapid biomass accumulation in the seed-down.

Due to perennial forages and native grassland species having a longer growing season, and generally, having deeper rooting depth than annual crops, they return more residue to the soil. Perennials also allocate more C from photosynthate to below-ground parts according to Smith *et al*., (1997), in order to extend the growing season and keep reserves for the next growing season. Thus, SOC may cycle more slowly and result in a more secure net amount in the subsoil (Paustian *et al*., 1990). Perennials also form an extensive network of roots that may enhance soil stable soil aggregate formation in the absence of tillage or disturbance and thus protect SOC from excessive oxidation.

LFOC the labile fraction of organic C, was consistently higher in the seed-down treatments compared to the cultivated treatments (table 1). This could be due to the return of more plant residue (no harvest of plant material) and undisturbed conditions, which would tend to decrease oxidation of organic C to CO_2. The differences were however, not significant at $p \leq 0.10$ expect for Site 6, where the comparison was between native grazed prairie and a cultivated equivalent.

LFOC, generally followed trends similar to SOC. There was typically a higher LFOC in treatments with significantly higher SOC. This trend is consistent with the results of other workers (Biederbeck *et al*., 1994). Overall, LFOC was lower in slope positions where decomposition of plant residue may be faster, due to more moisture.

EC values at all sites were low, indicating no salinity effects, except for the cultivated wetland fringe at Site 2 (Gayowski DNC Project). Except for Site 2, no discernible treatment effects on salinity were indicated. Overall however, no discernible trends due to salinity were indicated. Reaction showed landscape effect, with lower pH values in lower slope positions and higher pH values (around 8.2-9.2) in upper slope positions. The cultivated landscape, however, tended to show an increase in pH in all parts of the landscape, compared to the seed-down.

Conclusions

It was evident in this study that seed-down of marginal land to perennial grass forage mixes has an impact on SOC in the surface layer and that the treatment tended to increase it rather than decrease it. The effect on SOC storage (0-15 cm depth, may however, vary under different conditions, such as different soil textural classes and climatic zone. This study only dealt predominantly with loams and clay-loams in the Dark Brown and thin Black Soil Zones. Work is underway to determine to examine the effects of seed-down in the thick Black and Gray Soil Zones.

Out of 17 comparisons in the Meacham-Dana Area, grass seed-down increased SOC in 8, had no significant difference in 3, and lower trends in 6. LFOC appeared to be more sensitive to management as the seed-down consistently had more accumulation of LFOC. Shoulder positions were most consistently responsive to grass seed-down in terms of increasing SOC. Accumulation of C at greater depths than 0-15 cm over longer time periods should be considered. Efforts to increase plant residue return in marginal lands under no disturbance, such as done in DNCs, should result in net C storage in soils.

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Acknowledgements:

The authors wish to thank Richard McBride (Ducks Unlimited), Saskatoon, and Renny Grilz (Ducks Unlimited), Melfort, for technical help.

Financial support of AFIF, Agriculture Canada, Ducks Unlimited and GTAP are gratefully acknowledged.