Potential for Carbon Sequestration and Soil Quality Improvement with Forages

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Introduction

There is increased interest in Saskatchewan in the conversion of marginal annually cropped lands to permanent forage cover. Driving forces for this conversion include low commodity prices and high transportation costs for grains, increased demand for high quality livestock feed and forage seed, concerns over deterioration of soil quality, and programs intended to encourage conversion of marginal cropped lands to forages. Important considerations in such a change in land use are the potential effects on soil organic matter quantity and quality. Increases in soil organic matter provide a benefit to the land-owner in improved soil quality and also a benefit to society as the soil acts as a sink for carbon dioxide. Previous studies have examined the effect of conversion of cultivated land to perennial grass cover on soil organic carbon content in various regions of the world (Table 1).

Table 1. Examples of carbon sequestration rates with conversion of marginal agricultural soils to grasslands.

Region	Land Conversion	Time yrs	Soil Depth cm	C accumulation Mg C ha^{-1} yr^{-1}	Ref.
UK	Planted grassland	15	15	0.75	Tyson et al.1990
USA	Abandoned (tall grass)	17	10	1.0	Jastrow (1996)
Canada	Abandoned (short grass)	24	15	0.07-0.13	Dormaar & Smoliak (1985)

In Saskatchewan, there is limited information on how conversion to perennial forage grasses influences soil organic carbon and soil quality . The study described in this paper investigated soil organic carbon (SOC) mass, light fraction organic carbon (LFOC), and nitrogen and phosphorus supply rates in marginal cropped and disturbed land seeded down to perennial grasses over five to twelve years, in comparison to annually cultivated equivalents, in east-central Saskatchewan. A complete description of the study and results can be found in Mensah (2000, MSc thesis, Univ. of Sask.). This paper is intended to provide a general overview and summary of the study.

Sites

The sites were located near Meacham and Dana, SK in the Dark Brown-Thin Black Transition zone, and near Gronlid and Pleasantdale, SK in the Black – Gray transition zone. Where possible, catenas were selected for side-by-side comparison of annually cropped versus grass seed-down. The study areas were located in Ducks Unlimted conservation areas which enabled documentation of the site history as to seeded species and management history since establishment of the grass seed-down.

The majority of comparisons were between annually cultivated and 5 to 12 years after seed-down to a mixture of native and introduced species, including wheat grasses, brome grasses, needle grasses and legumes such as alfalfa. The cropping systems compared varied in rotation and tillage system from cereal-fallow conventional tillage to multi-crop direct seeded.

Materials and Methods

Five soil cores (10 cm diameter, 15 cm depth) were taken at random from a 25m^2 sampling area at each slope position: shoulder, backslope, footslope, wetland fringe in the cultivated and seed-down catenas. The cores were sectioned into 0-5 cm, 5-10 cm and 10-15 cm depth increments and air-dried for bulk density determination. The soil organic carbon (SOC) mass was determined by dry combustion using a LECO C analyzer. Light fraction organic carbon (LFOC) was determined by flotation in sodium iodide and measurement by dry combustion. Nitrate and phosphate supply rates in intact cores were assessed over four weeks using PRS™ resin membrane probes placed directly in cores at a moisture content of ~ 90% of field capacity. Data was analyzed using MINITAB two-sample t-tests, assuming unequal variances, since Bartlett's homogeneity of variance test on the data showed evidence of unequal variances. An alpha value of 0.10 was chosen as the confidence level for all paired comparisons.

Results and Discussion

Individual comparisons of SOC in annually cultivated versus grass seed-down pairs usually, but not always, revealed significantly higher organic carbon mass in the top 15 cm of the seed-down than in the cultivated comparable. The average amounts of SOC (0-15 cm) across the landscapes for the comparisons in each study region are shown in Table 2.

Table 2. Average amounts of soil organic carbon (0-15cm) in forage seed-down and cultivated comparisons in the three study regions.

Study Area	**Seed-down**	**Cultivated**
	-------------------Mg C ha^{-1}------------------	
Meacham	59.4 $\pm$ 4.1	52.6 $\pm$ 2.6
Dana	43.1 $\pm$ 2.5	36.1 $\pm$ 1.9
Gronlid	44.5 $\pm$ 4.5	25.5 $\pm$ 3.1

The net rate of SOC gain (0-15 cm) in the grass seed-downs in the Meacham study area was estimated to be 0.8 Mg C $ha^{-1}yr^{-1}$, based on the SOC mass difference between the treatments and average age of the seed-downs. The combined analysis using the 6 comparisons in the Dana area revealed a net rate of C gain of 0.9 Mg C $ha^{-1}yr^{-1}$. For comparisons in the Gronlid-Pleasantdale study area, the net C gain rate was estimated to range from 1.5 to 1.9 Mg C $ha^{-1}yr^{-1}$, which may be an overestimate due to uncertainty about the age of some of the treatments and possible non-equivalent matches. However, higher rates of carbon gain in more moist soil-climatic zones would be expected.

In the landscape, shoulder positions and eroded areas were most responsive to carbon gains from seed-down to perennial grasses. The carbon accumulation by perennial grasses is attributable to high allocation of carbon below ground, greater transpiration leading to drier soils, formation of stable aggregates and the absence of cultivation. Mixed grasses in the seed-down are better able to use subsoil moisture due to species having extensive rooting habits as well as fine roots. Apparent carbon gains were more pronounced where the cultivated equivalent involved a short rotation (e.g. cereal-fallow) and a high degree of tillage. Overall, the estimates of net SOC gain rates in this study (0.6 to 1.2 Mg C $ha^{-1}yr^{-1}$) are consistent with estimates made in the U.S. Conservation Reserve Program studies and concur with established estimates for seeded grasslands over this period of time.

The light fraction organic carbon (LFOC) mass and proportion of soil organic carbon comprised of light fraction organic carbon (%LFOC) were higher in the surface (0-5cm) of the grass seed-downs than in the cultivated treatments. Data for % LFOC in three comparisons at the Meacham study area is shown in Table 3.

Table 3. Mean light fraction proportions of SOC (% LFOC) in the 0-5 cm depth in shoulder positions of three comparisons at the Meacham study area.

Site	Seed-down	Cultivated
	----------% LFOC in SOC--------	
Hanuschuk	15.8	5.5
LeBlanc	14.3	9.9
Sopatyk	21.1	11.8

The LFOC is considered to represent the recent, easily decomposable portion of soil organic carbon, derived from recent residue inputs. In this study, the %LFOC/SOC was not strongly related to observed patterns of SOC. However, as % LFOC reflects recent C residue inputs in relation to stable humus, it is anticipated that a high %LFOC indicates a system that is more rapidly gaining SOC, but not necessarily of high SOC content at this time. Therefore, %LFOC can be useful as an indicator of those systems which are rapidly gaining soil organic matter.

The supply rates of nitrate and phosphate released over time to a resin membrane probe are useful as an indicator of nutrient availability and mineralization potential as affected by management. Significantly higher initial nitrate and phosphate supply rates were observed in many cultivated treatments than in the grass seed-downs, likely due to residual fertilizer nitrogen and phosphorus. However, increases in nitrate supply rates in the seed-downs over time suggest higher N mineralization potential in the seed-down treatments than the cultivated equivalents. Seed-downs that included a forage legume like alfalfa showed consistent and significantly higher N supply rates than pure grass seed-downs. However, the alfalfa managements often showed low P supply, likely due to more P removed in alfalfa harvest. As such, low P availability may be limiting C accumulation potential in the systems.

Conclusion

Seeding of grasses and forage legumes appears to have a general positive effect on surface soil organic carbon stores in marginal soils in east-central and north-eastern Saskatchewan. Based on the results of this study, which looked at seed-downs in place for five to twelve years, carbon sequestration rates are estimated to be 0.6 to 1.2 Mg C $ha^{-1} yr^{-1}$. Indicators of soil quality such as SOC, % LFOC and supply rates of available nutrient from mineralization were generally positively influenced by the forage seed-down. Limitations in this study include uncertainty in the validity of the assumption that all paired comparisons were representative matches, equivalent in soil carbon content prior to the seed-down and at a steady state. As well, this study only looked at carbon differences in the top 15 cm. Future research should examine potential SOC mass differences deeper than 15 cm, especially in low slope positions and the wetland fringe. The effect of conversion to forages should also be studied in drier soil climatic regions such as the Brown and Dark Brown soil zones.

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