Effect of Cropping Frequency on C Storage in Canadian Prairie Soils

C.A. Campbell[1], R.P. Zentner[2], H.H. Janzen[3] and G.P. Lafond[4]

[1]Eastern Cereals and Oilseeds Research Centre, Ottawa, ON.
[2]Semiarid Prairie Agricultural Research Centre, Swift Current, SK.
[3]Lethbridge Research Centre, Lethbridge, AB., [4]Indian Head Research Farm, Indian Head, SK.

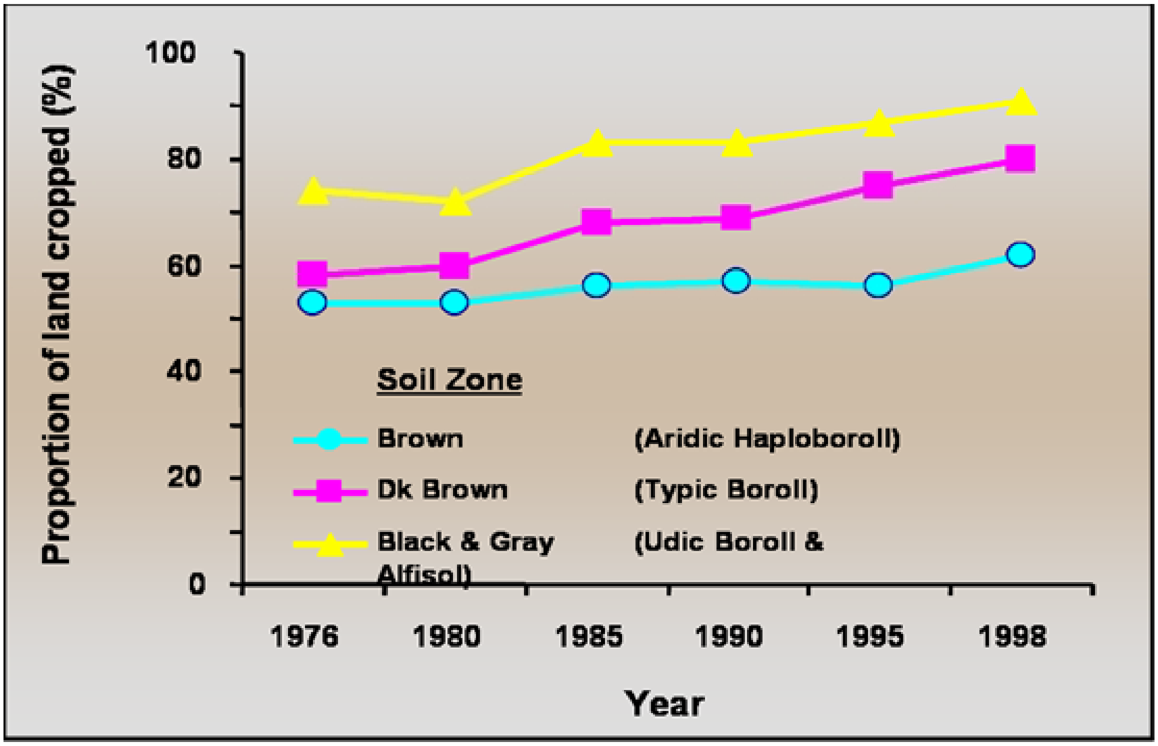
Abstract

Available water is the main constraint to crop production on the Canadian prairies. Summerfallow has been used to counter this problem, but frequent summerfallowing promotes soil organic matter (SOC) loss. Although summerfallow use has decreased substantially over the past 20 years, there is still considerable land devoted to this practice each year. This paper reviews research literature and assesses the influence of cropping frequency on SOC and discusses how this is influenced by ecoregion, tillage, fertility, and crop type. Results from 17 studies in the Canadian prairies were analyzed. In most soils, SOC increased with cropping frequency, but this relationship was not linear. In semiarid regions, SOC gains under no-till management were about 250 kg ha^{-1} yr^{-1} greater than for tilled systems at any specified cropping frequency; in subhumid environments, this advantage ranged from 50 kg ha^{-1} yr^{-1} for fallow-crop-crop rotations to 250 kg ha^{-1} yr^{-1} for continuously cropped rotations. In tilled systems, SOC gains were unaffected by soil zone. SOC gains in wheat-lentil rotations were similar to those in continuous wheat, but when low yielding flax replaced wheat in the rotation, SOC gains were substantially lower. Replacing wheat with fall rye increased SOC gains significantly, because of greater N efficiency and erosion control with the latter. Cropping frequency had no effect on SOC gains in unfertilized systems, but in systems fertilized according to soil tests, SOC gains were directly proportional to cropping frequency (except in the high SOC thick Black Chernozems such as at Melfort).

Introduction

Available water main constraint to production.
Summerfallow used to counter this problem.
Summerfallow leads to loss of SOC.
Considerable summerfallow still practiced but acreage has decreased markedly (Fig. 1).

Figure 1. Changes in cropping intensity on the Canadian prairies (1976-1998)
(Fallow frequency = 100% - cropping frequency).



Objective
Review literature and assess influence of cropping frequency on SOC.

Methodology
Determine how SOC changes are influenced by ecoregion, tillage, fertility and type of crop.

Seventeen long-term studies in the Canadian prairies were selected for analysis (included summerfallow treatments).

Accuracy of our findings constrained by pitfalls often encountered in quantifying changes in SOC (e.g., small, slow changes; large spatial variability; inadequacies in sampling and analyzing SOC).

SOC changes depend on degree to which SOC already degraded; the more degraded the soil, the easier to reverse change.

Most experiments assessed were initiated on land already degraded by fallow.

Caution: ***We often simplified results by expressing SOC change as linear functions, but recognize that changes are curvilinear and not indefinite.***

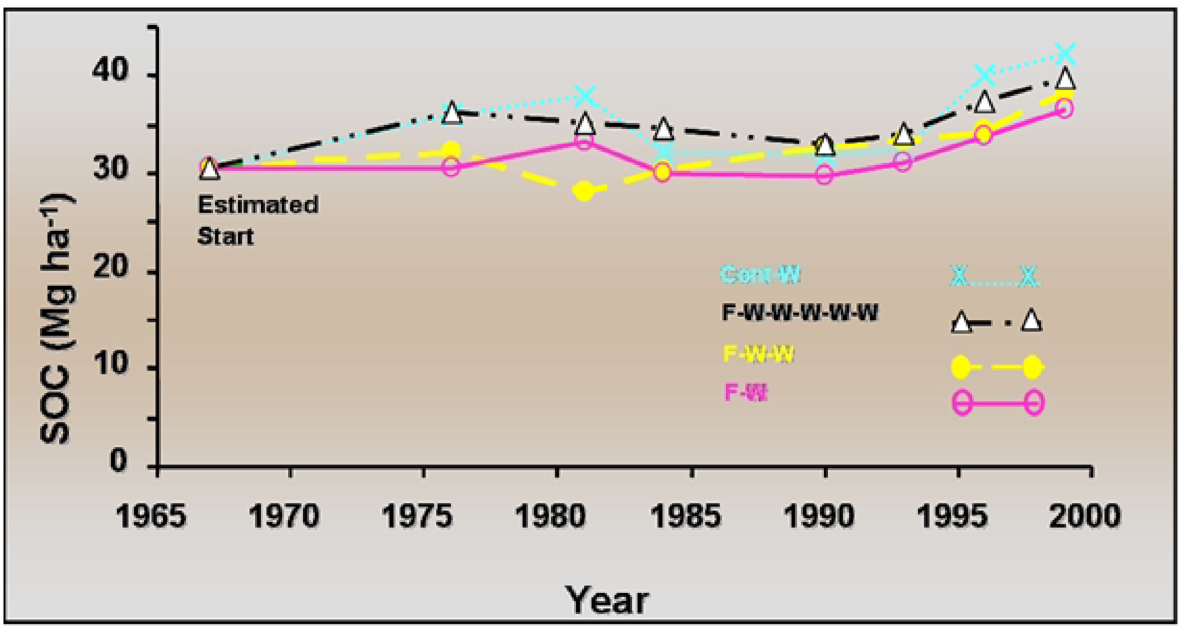
Definitions and Abbreviations

Rotation phase	Abbreviation		Cropping Frequency (%)	Fallow Frequency (%)
Fallow	F	F-W	= 50	= 50
Spring wheat	W	F-W-W	= 66	= 33
Flax	Flx	F-W-W-W	= 75	= 25
Fall rye	Rye	F-W-W-W-W	= 80	= 20
Continuous crop	Cont	Cont crop	= 100	= 0

[Note: F-W-W-W-W-W was derived in 1985 from two rotations: {oat(hay)-W-W and Flx-W-W, N+P}]

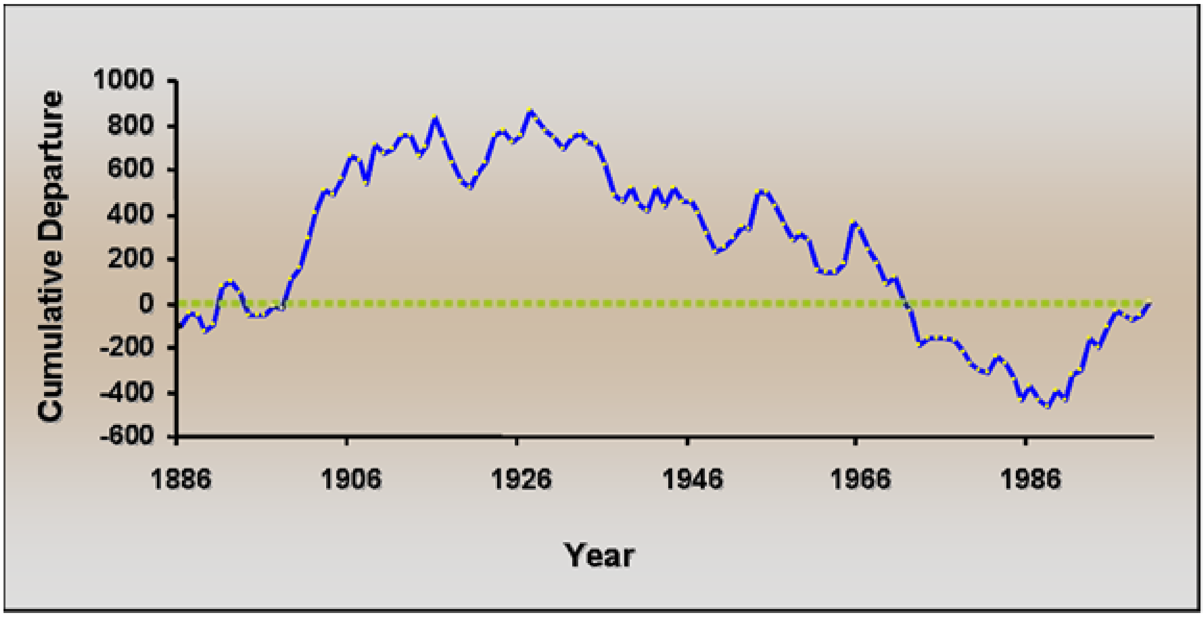
Results

Figure 2. Effect of cropping frequency on SOC trends (1967-1999) in Swift Current Old Rotation Study (0-15 cm depth).



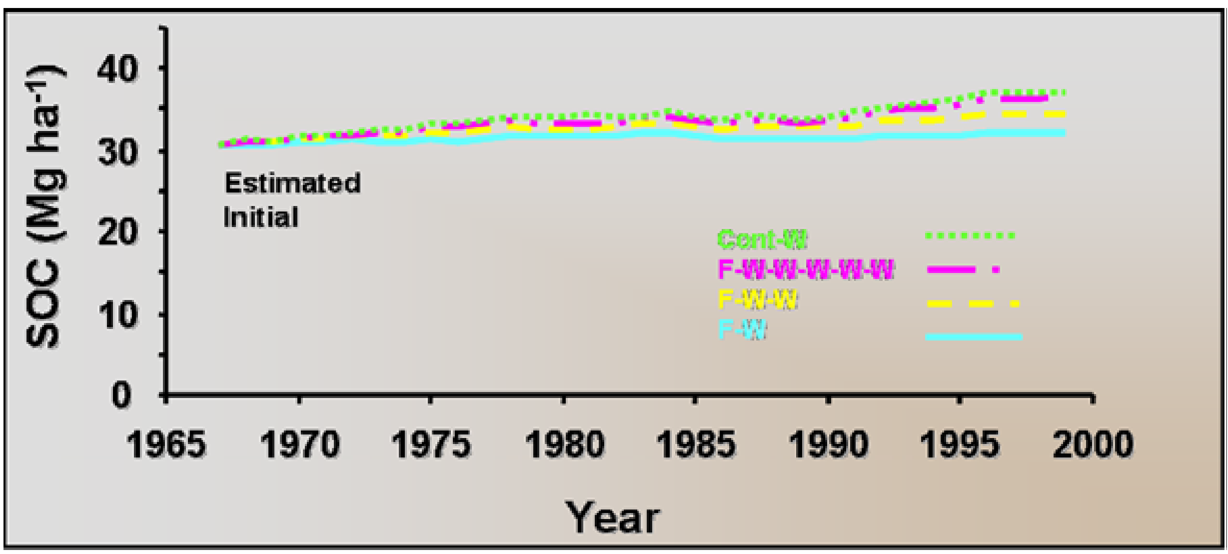
Old Rotation experiment at Swift Current initiated in1967 on land that had been in wheat-fallow with mostly P fertilizer applied for previous 60-70 years. Soil organic C remained constant in frequently fallowed systems until 1990, then increased to 1980 in systems with adequate fertilization and high cropping frequency (Fig. 2). SOC in all systems increased after 1990 due to above average growing season precipitation (Fig 3). Although trends are variable, there is a direct relationship between SOC and cropping frequency.

Figure 3. Yearly accumulated departure from normal growing season precipitation (MJJA) at Swift Current (1886 - 2000).



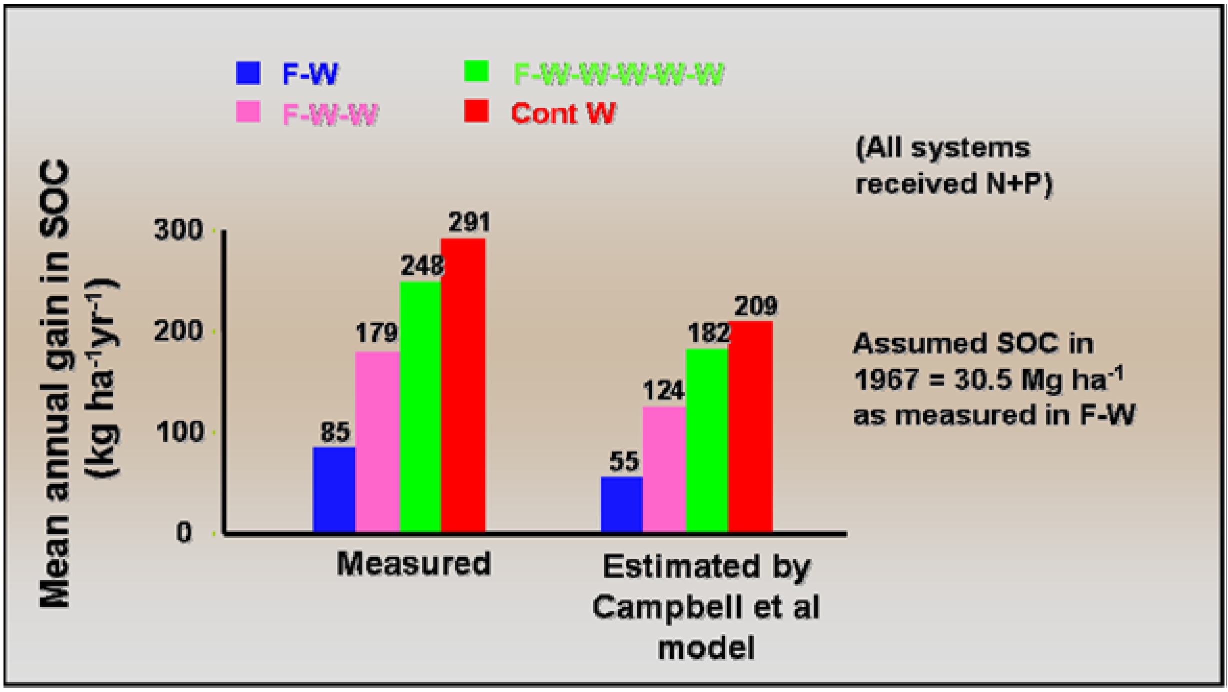
In this plot, positive slopes correspond to periods of above average precipitation (e.g., 1886-1915 and 1989-2000); negative slopes correspond to periods of drought (e.g., 1930-1988).

Figure 4. Effect of cropping frequency on SOC trends (1967-1999) in Swift Current Old Rotation Study (estimated by model of Campbell et al.).



The Campbell et al. (2000) SOC model effectively simulated the effect of cropping frequency on trends in SOC in the Old Rotation experiment at Swift Current (Fig. 4).

Figure 5. Change in SOC (1967-1999) in 0-15 cm depth in Swift Current Old Rotation Study: Measured and estimated by model of Campbell et al. <u>Effect of cropping frequency.</u>



The rate of change in SOC in Old Rotation experiment at Swift Current between 1967-1999 increased with cropping frequency, from 85 kg ha^{-1} yr^{-1} for F-W to 291 kg ha^{-1} yr^{-1} for Cont W (measured) (Fig. 5). Values estimated by the Campbell et al. model were similar in trend but about two-thirds in magnitude relative to measured values (Fig. 6). Further, the relationship between rate of change in SOC and cropping frequency was not linear.

Figure 6. Effect of cropping frequency on rate of change in SOC (0-15 cm depth) in Old Rotation Study at Swift Current, SK (1967 – 1999).

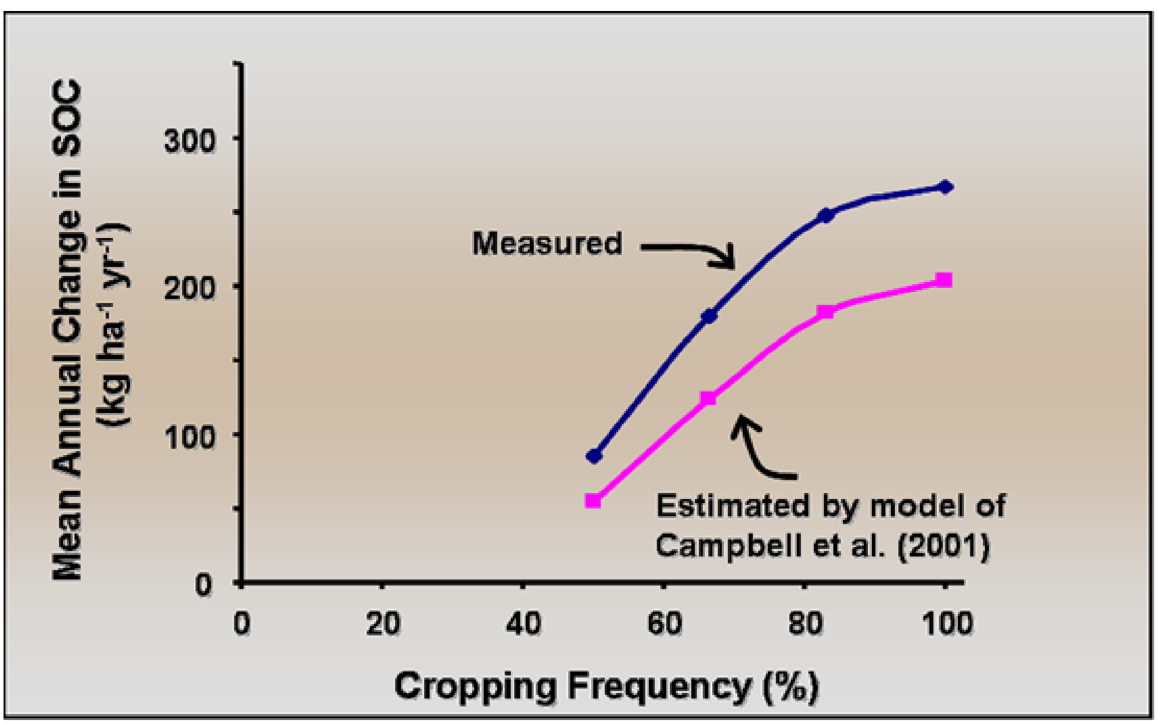
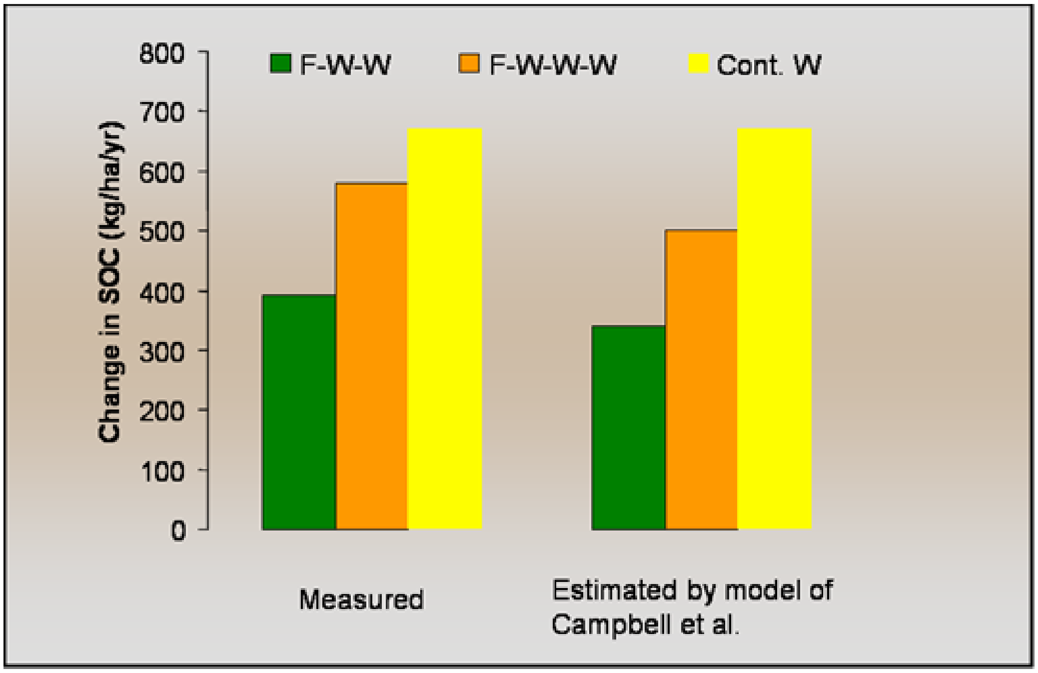
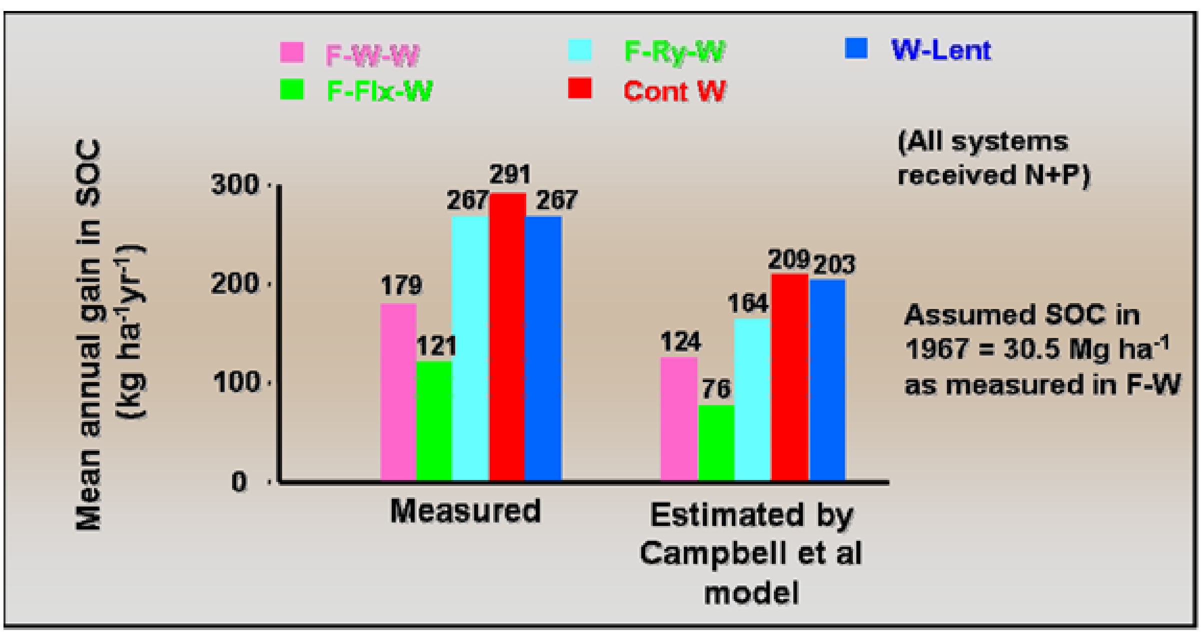


Figure 7. Change in SOC (1987-1996) in 0-15 cm depth in Swift Current New Rotation Study: Effect of cropping frequency.



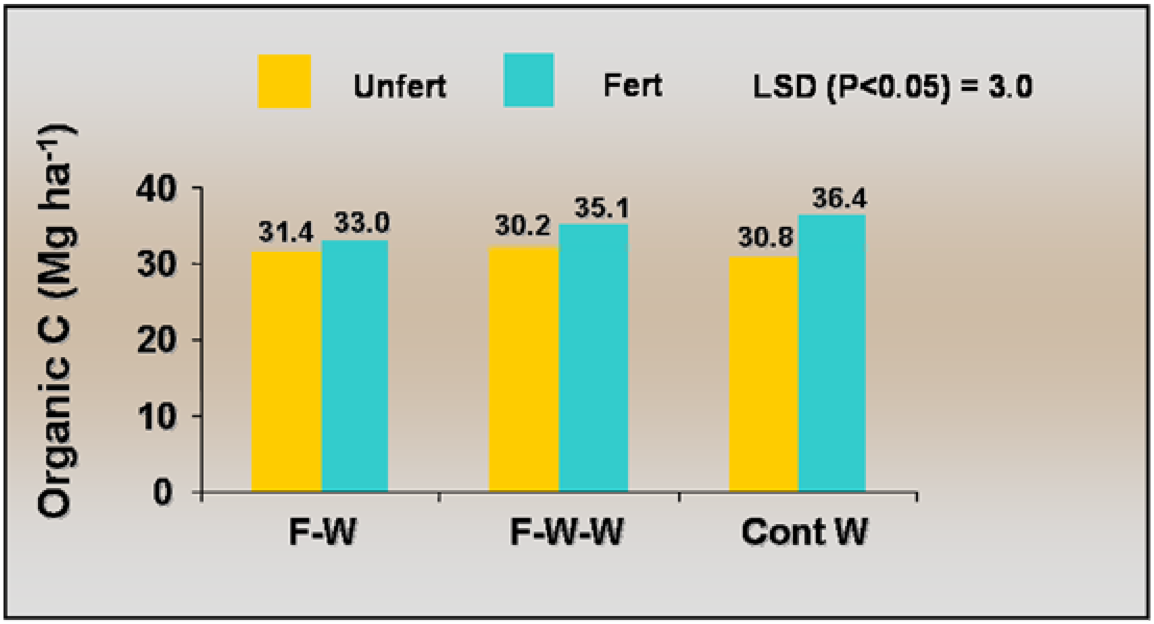
In the New Rotation experiment at Swift Current, which was conducted under more favourable moisture conditions than the Old Rotation study, rates of change in SOC were much larger and the Campbell et al. model fit the data more closely (Fig. 7).

Figure 8. Change in SOC (1967-1999) in 0-15 cm depth in Swift Current Old Rotation Study: measured and estimated by model of Campbell et al. Effect of crop type.



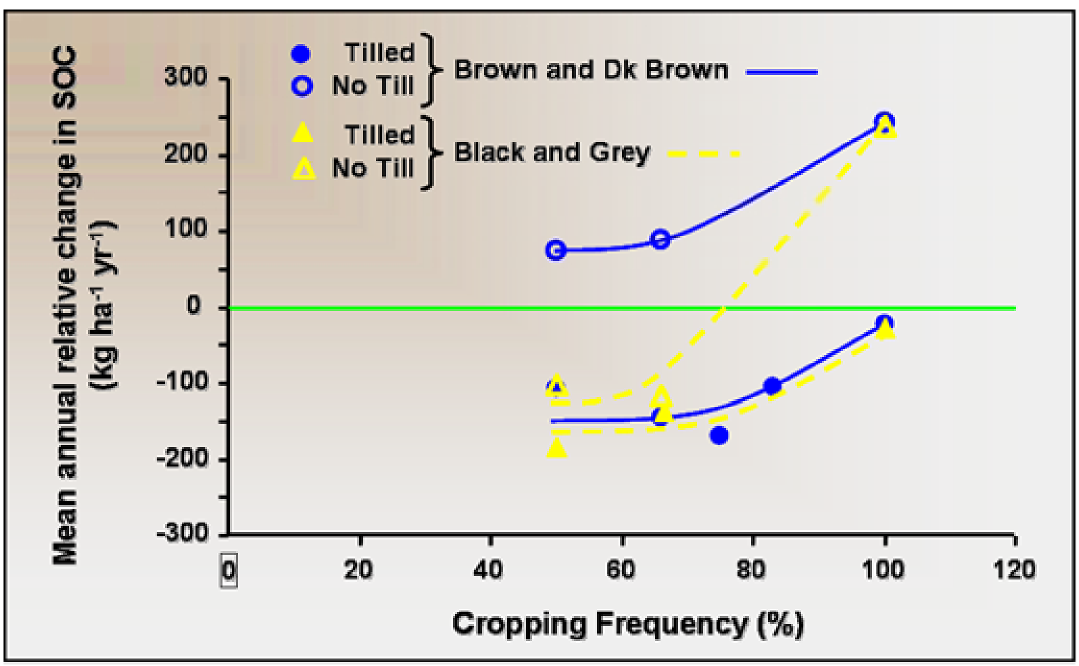
Gains in SOC were similar for the wheat-lentil rotation as for continuous wheat, but when low yielding flax replaced wheat SOC gains were lower (Fig. 8). Replacing wheat with the efficient N using, low erosion fall rye system increased SOC gains.

Figure 9. Effect of N & P fertilizer and cropping frequency on SOC in 0-15 cm depth in a thin Black Chernozem at Indian Head after 40 years.



Cropping frequency had no effect on SOC gains in unfertilized systems, but in systems fertilized based on soil tests, SOC gains were directly proportional to cropping frequency (Fig. 9) (except in thick Black Chernozems such as at Melfort – data not shown).

Figure 10. Effect of cropping frequency on mean annual rate of change in SOC (0-15 cm depth) relative to conv. till, fertilized, cont. crop system (Control).



In semiarid regions (e.g., Brown and Dark Brown soils), SOC gains under no-till management were about 250 kg ha-1 yr-1 greater than for tilled systems at any specified cropping frequency; in subhumid environments (Black and Gray soils), this advantage ranged from 50 kg ha-1 yr-1 for fallow-crop or fallow-crop-crop rotations to 250 kg ha-1 yr-1 for continuous cropped rotations (Fig. 10). In tilled systems, SOC gains were unaffected by soil zone. (Data summarized from 17 experiments, 7 in the Brown, 4 Dark Brown, 5 in Black, and 1 Gray Luvisol.).

References

Campbell, C.A., Zentner, R.P., Liang, B.C., Gregorich, E.G., Roloff, G. and Blomert, B. 2000. Organic C. accumulation in soil over 30 years in semiarid southwestern Saskatchewan – Effect of crop rotations and fertilizers. Can. J. Soil Sci. 80:179-192.