Long-term Straw Management and N Fertilizer Rate Effects on Soil Organic C and N, and Some Chemical Properties in a Gray Luvisol

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Introduction

- Due to recent developments in Kyoto protocol, there is a great interest to identify management practices that enhance carbon (C) sequestration in soil.
- Because the amounts of annual inputs and outputs of plant residue C are usually much smaller compared to the amounts of organic C present in the soil, it is difficult to detect changes in organic C in soil, especially in the short duration.
- Long-term studies provide such information to determine the best management practices for sustainable soil quality and productivity.
- Crop residues are a source of soil organic matter, which is the primary source and temporary sink of plant nutrients, and energy source for soil microorganisms.
- Crop residue and fertilizer management practices alter some soil properties, but the magnitude of change depends on soil type and climatic conditions.

Objective

To determine the effects of 27 years (from 1983 to 2009 growing seasons) of straw management [straw removed (S_{Rem}) and straw retained (S_{Ret})] and N fertilizer rate (0, 25, 50 and 75 kg N ha^{-1}) on soil biochemical [total organic C (TOC) and N (TON), light fraction organic C (LFOC) and N (LFON)], and chemical (pH, extractable P, ammonium-N and nitrate-N) properties under conventional tillage.

Materials and Methods

- Field experiment with mainly barley (and canola, wheat, triticale, or pea in a few years) was conducted on a Gray Luvisol (Typic Cryoboralf) loam at Breton, Alberta, Canada.
- The treatments included two straw management (straw removed [S_{Rem}] and straw retained [S_{Ret}]) and four N (0, 25, 50 and 75 kg N ha^{-1}) under conventional tillage (tilled twice, once in the autumn and once in the spring, with a chisel cultivator followed by a coil packer) in a RCBD in four replications.
- The crop was harvested every year from 1983 to 2009 for seed and straw yield.
- In autumn 2009, soil samples were taken in eight treatments where N fertilizer urea was broadcast and incorporated into soil in spring just prior to seeding, and then analyzed for various organic C and N fractions.
- The calculated data for each parameter were subjected to analysis of variance (ANOVA). Significant ($p \leq 0.05$) differences between treatments were determined

using least significant difference ($LSD_{0.05}$) test. Correlations between TOC, TON, LFOC and LFON, and linear regressions for relationships between crop residue C input from 1983 to 2009 growing seasons and soil organic C or N (TOC, TON, LFOC, LFON) stored in soil were calculated using the linear (REG) procedure.

Summary

- S_{Ret} and N fertilizer treatments usually had higher mass of TOC,TON, LFOC and LFON in soil.
- There were highly significant correlations among most soil organic C or N fractions. Linear regressions between crop residue C input and soil organic C or N were significant in most cases.
- There was no effect of residue management on soil pH, but application of N fertilizer reduced pH significantly in the top 15 cm soil.
- Extractable P in the 0-15 cm soil layer tended to be higher with S_{Ret} than S_{Rem} in many cases, but it decreased significantly with N application.
- Residual nitrate-N (though quite low) increased with application of N and also indicated some downward movement in the soil profile up to 90 cm depth.
- There was generally no effect of any treatment on ammonium-N in soil.

Conclusions

- Straw retention and N application improved both total and light fraction organic C and N in soil, and generally the differences were more pronounced for light fraction organic C and N, and between the most extreme treatments (S_{Rem}0 vs. S_{Ret}75).
- Retention of straw tended to increase extractable P in the surface soil, but application of N fertilizer reduced it. Application of N fertilizer reduced pH in the surface soil, and showed accumulation and downward leaching of nitrate-N in the soil profile.

Acknowledgements

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Table 1. Relationships among soil organic C or N fractions (TOC, TON, LFOC, LFON), or between crop residue C input from 1983 to 2009 growing seasons and organic C or N stored in soil sampled in autumn 2009 at Breton (Gray Luvisol), Alberta, Canada (experiments established in autumn, 1983)

Parameter	Correlation coefficients			
	TOC	TON	LFOC	LFON
Relationships among soil organic C or N fractions				
TOC		0.960***	0.855**	0.843**
TON			0.792*	0.773*
LFOC				0.993***
LFON				

Table 2. Linear regressions for relationships between crop residue C input from 1983 to 2009 growing seasons and organic C or N (TOC, TON, LFOC, LFON) stored in soil sampled in autumn 2009at Breton (Gray Luvisol), Alberta, Canada (experiments established in autumn, 1983)

Crop parameter (X)	Soil C or N parameter (Y)	[z]Linear regression (Y = a + bX)	R^2
Crop residue C input	TOC	Y = 14.20 + 0.3627X	0.954**
	TON	Y = 1.418 + 0.0279X	0.892*
	LFOC	Y = 303.55 + 33.94X	0.997**
	LFON	Y = 8.708 + 1.3484X	0.994**

[z]Y = Soil organic C or N fraction (TOC and TON as Mg C or N ha^{-1}; and LFOC, LFON as kg C or N ha^{-1}; a = Intercept on Y, origin of the line; b = Regression coefficient of Y on X, slope of line; X = Crop residue C input (Mg ha^{-1}).

*, ** and ns refer to significant treatment effects in ANOVA at P ≤ 0.05, P ≤ 0.01 and not significant, respectively.

Table 3. Linear regressions for relationships between the amount of N applied in various treatments from 1983 to 2009 (0, 675, 1350 and 2025 kg N ha^{-1}) and organic C or N (TOC, TON, LFOC, LFON) stored in soil sampled in autumn 2009 at Breton (Gray Luvisol), Alberta, Canada (experiments established in autumn, 1983)

Amount of N applied (X)	Soil C or N parameter (Y)	[z]Linear regression (Y = a + bX)	R^2
Amount of N applied in	TOC	Y = 18.99 + 0.1172X	0.997**
	TON	Y = 1.856 + 0.0081X	0.882*
	LFOC	Y = 879.5 + 6.3922X	0.713^{ns}
	LFON	Y = 31.76 + 0.2302X	0.680^{ns}
Amount of N applied in	TOC	Y = 20.71 + 0.1041X	0.934**
	TON	Y = 1.8474 + 0.009X	0.914*
	LFOC	Y = 802.66 + 13.88X	0.985**
	LFON	Y = 28.41 + 0.5741X	0.997**

[z]Y = Soil organic C or N fraction (TOC and TON as Mg C or N ha^{-1}; and LFOC, LFON as kg C or N ha^{-1}; a = Intercept on Y, origin of the line; b = Regression coefficient of Y on X, slope of line; X = Amount of N applied in various treatments from 1983 to 2009 (kg ha^{-1}).

*, ** and ns refer to significant treatment effects in ANOVA at P ≤ 0.05, P ≤ 0.01 and not significant, respectively.

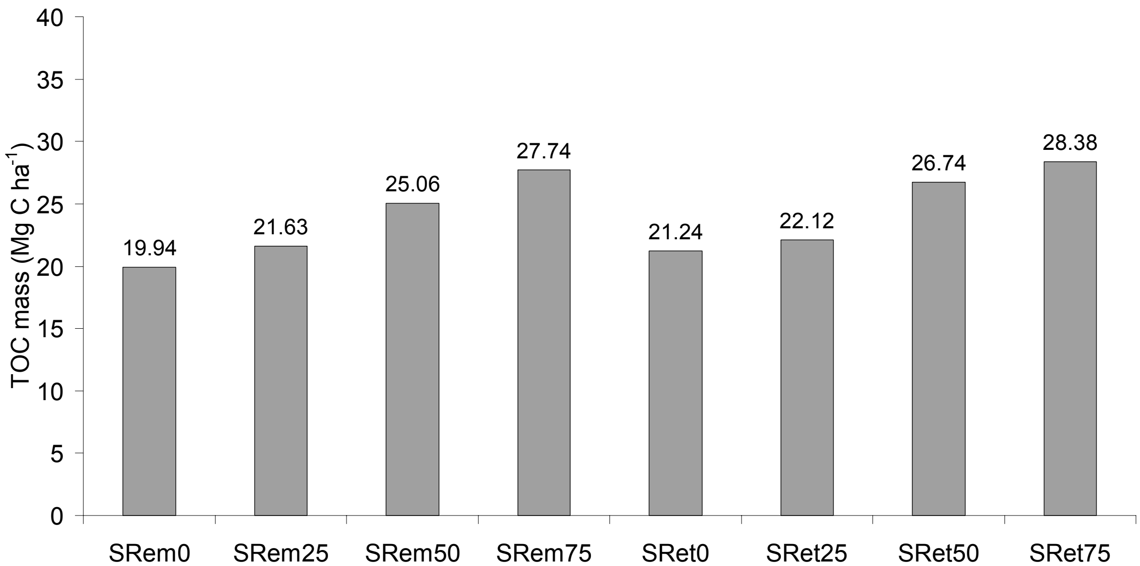

Figure 1. Effect of long-term straw management and N fertilizer rate on mass of total organic C (TOC) in soil (0-15 cm) in autumn 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn 1983 ; SEM = 1.159***).

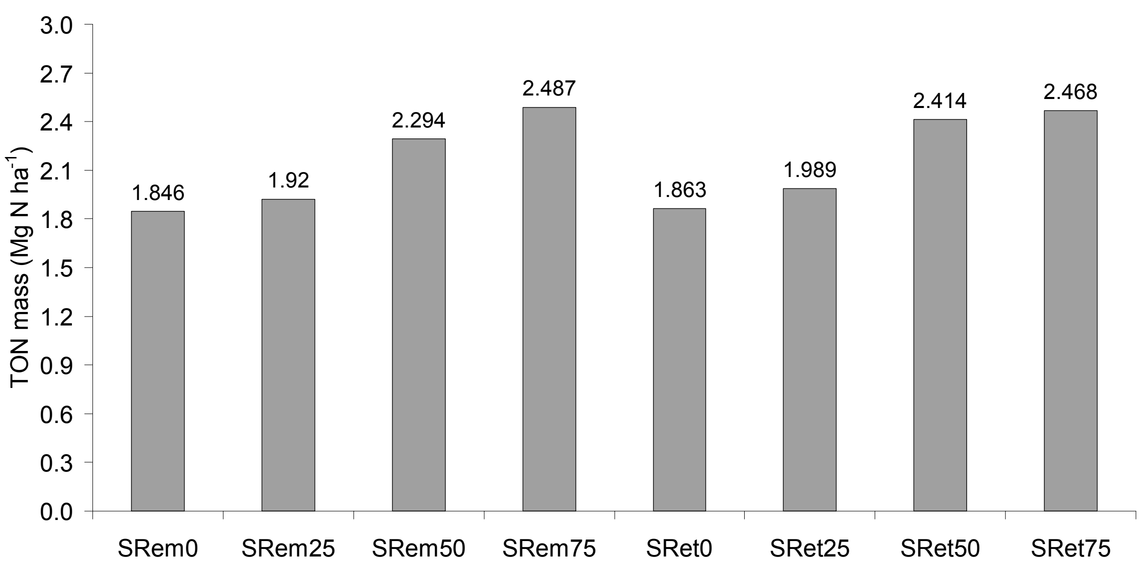

Figure 2. Effect of long-term straw management and N fertilizer rate on mass of total organic N (TON) in soil (0-15 cm) in autumn 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn 1983 ; SEM = 0.1105***).

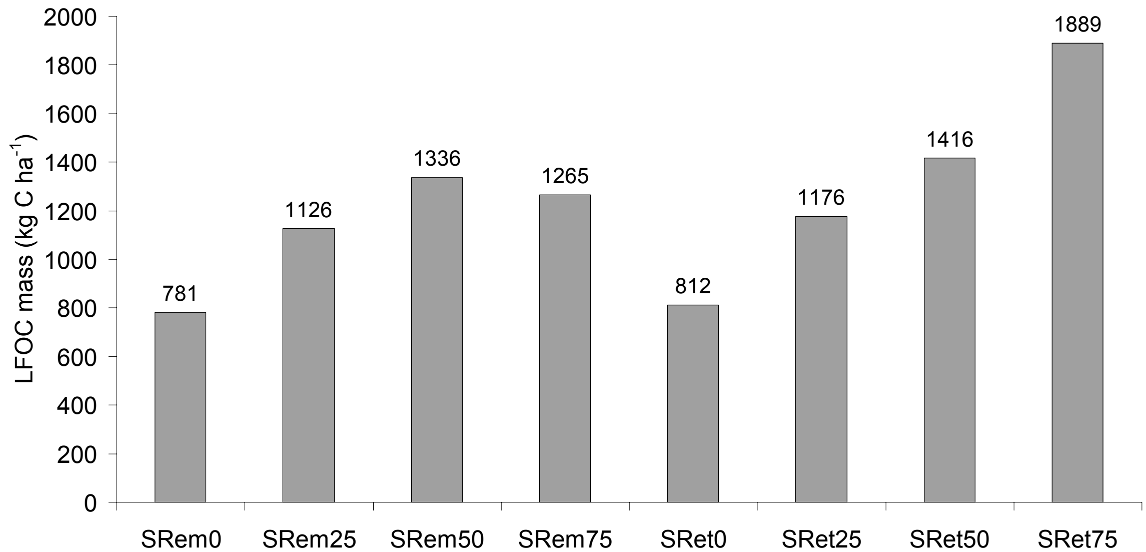

Figure 3. Effect of long-term straw management and N fertilizer rate on mass of light fraction organic C (LFOC) in soil (0-15 cm) in autumn 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn 1983 ; SEM = 122.8***).

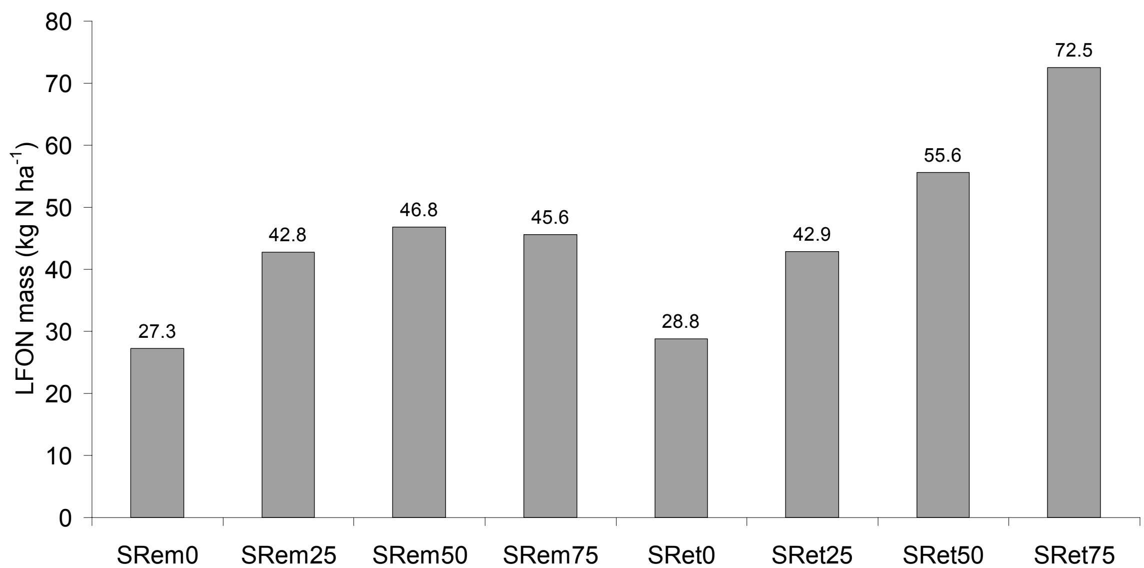

Figure 4. Effect of long-term straw management and N fertilizer rate on mass of light fraction organic N (LFON) in soil (0-15 cm) in autumn 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn 1983 ; SEM = 4.11***).

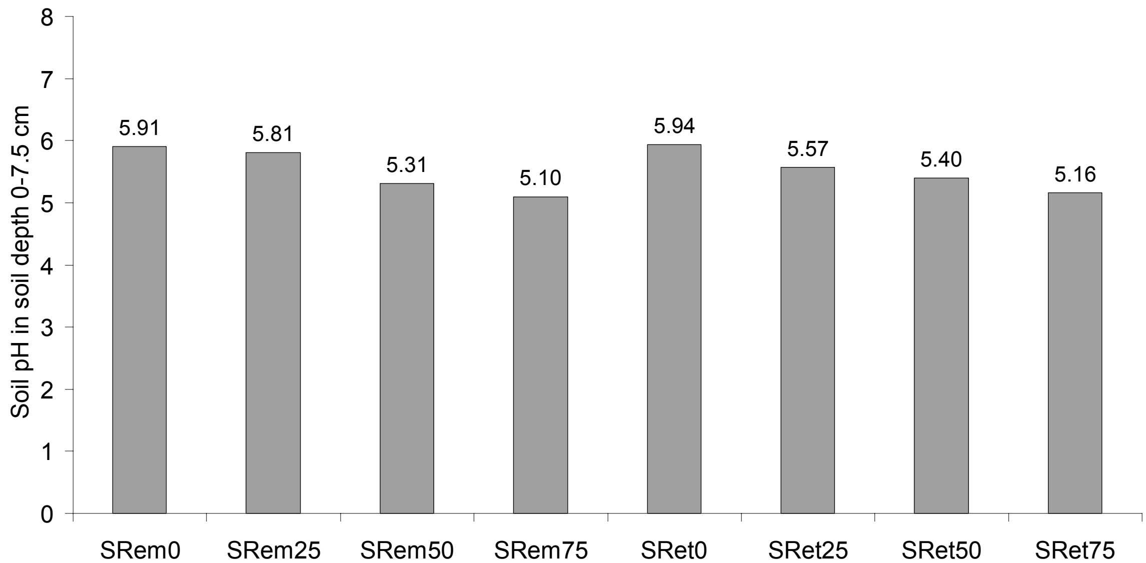

Figure 5. Effect of long-term straw management and N fertilizer rate on pH in soil (0-7.5 cm) in autumn 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn 1983 ; SEM = 0.103***).

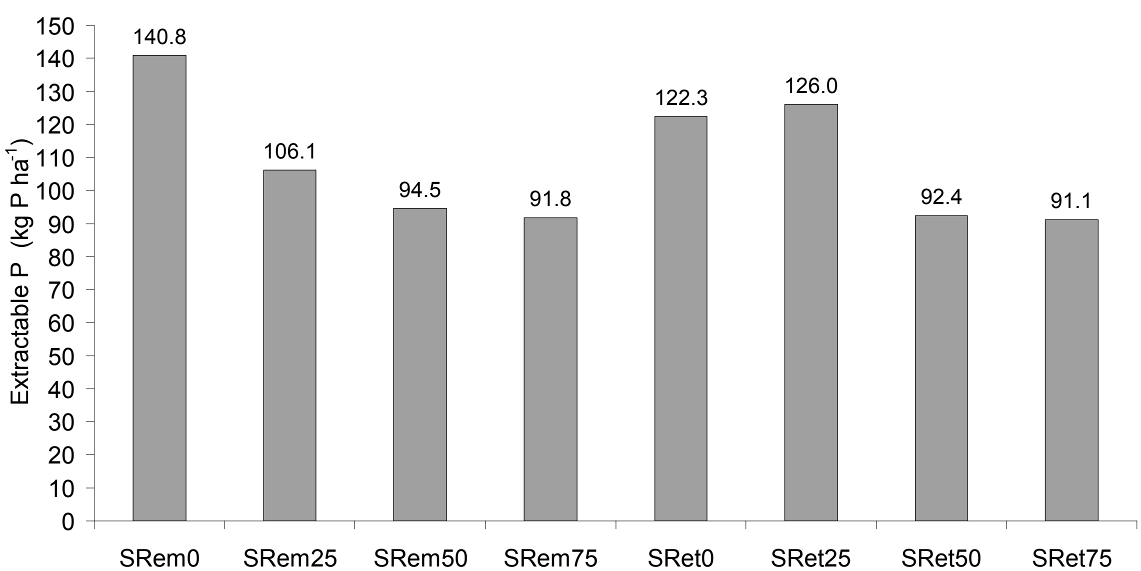

Figure 6. Effect of long-term straw management and N fertilizer rate on extractable P in soil (0-90 cm) in autumn 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn 1983 ; SEM = 12.01*).

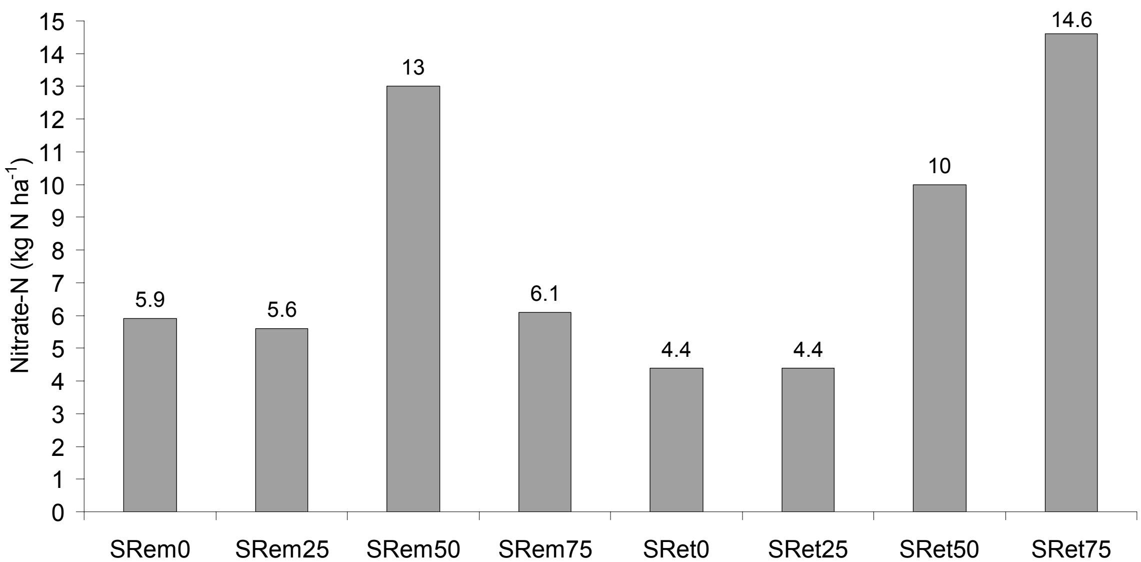

Figure 7. Effect of long-term straw management and N fertilizer rate on nitrate-N in soil (0-90cm) in autumn 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn 1983 ; SEM = 1.63***).