Soil Structure, C, and N Changes under Different Management Systems in Northern Alberta, Canada

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RATIONALE

Recommendations for sustained crop production and enhanced soil quality often include:

- **diversified crop rotation**
- reduction in tillage intensity

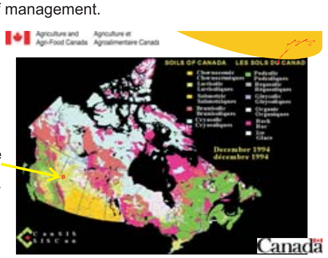
However, the effects of crop rotation and reduced tillage intensity are often site specific.

OBJECTIVE

Evaluate the effect of crop rotation on:

- **soil structure**
- soil carbon storage
- quality of organic C and N

in a semiarid region of northwestern Canada at the end of 10 years of management.



Beaverlodge in the Peace River region of northern Alberta

MATERIALS and METHODS

Environment

- mean annual temperature, 2 °C
- mean annual precipitation, 452 mm
- mean growing season conditions (May - August)
  - temperature, 12.5 °C
  - precipitation, 228 mm
  - class-A pan evaporation, 831 mm
  - growing degree days (≥5 °C), 1224 °C-days

Soil

- silt loam (Mollic Cryoboralf) near Beaverlodge AB
- initial characteristics to a depth of 20 cm (1992)
  - 22% sand, 44% silt, 34% clay
  - 38 g organic C kg^{-1} soil
  - 5.1 pH (1:2, soil:0.01 *M* $CaCl_2$)
  - 28 $cmol_c$ kg^{-1} soil

Management systems

- established in 1992
- 6 crop rotations evaluated
  - continuous bromegrass (*Bromus inermis* L.)
  - continuous fescue (*Festuca rubra* L.)
  - wheat-wheat-canola (*Brassica campestris* L.)
  - wheat (*Triticum aestivum* L.)-wheat-fallow
  - wheat-wheat-pea (*Pisum sativum* L.)
  - wheat-wheat-wheat
- tillage was minimal with harrowing to distribute straw and glyphosate to control weeds
- fallow managed with glyphosate to control weeds
- all phases of rotation present each year
- crops planted in mid May

Experimental design

- randomized complete block with 4 replications

Soil analyses

- collected in spring 2002 (at the end of 10 years)
- composite of 8 cores (25-mm diam) equidistantly along a diagonal transect in center between previous rows
- soil air-dried, gently crushed to <5.6 mm
- aggregate-size distribution and mean-weight diameter by wet sieving
- soil organic C and N by wet digestion
- light-fraction dispersed with NaI at 1.7 g · cm^{-3}
- soil microbial biomass C with $CHCl_3$ fumigation-incubation (10 d, 25 °C): CO_2-$C_{fumigated}$ / 0.41
- potential N mineralization during 24 d (inorganic $N_{24\,d - 0\,d}$)

Technical support

Thanks to Rahman Azooz

RESULTS

Aggregate-size distribution

Rotation	Water-stable aggregation class (mm) <0.25	0.25-1.0	>1.0
	------ % of soil ------		
Bromegrass	15	29	**56**
Fescue	20	27	**53**
W-W-Canola	25	**35**	40
W-W-Fallow	**27**	**32**	41
W-W-Pea	**29**	30	41
W-W-Wheat	**28**	27	45
$LSD_{(p = 0.05)}$	3	4	8

W is wheat.

Bromegrass and fescue had the highest percentage of large macroaggregates (>1 mm), while rotations with canola and fallow had the highest percentage of small macroaggregates (0.25-1 mm).

Light fraction

Rotation	Mass	Carbon	Nitrogen
	mg · g^{-1} soil	mg · g^{-1} LF	mg · g^{-1} LF
Bromegrass	15	182	13
Fescue	14	**222**	**15**
W-W-Canola	16	195	14
W-W-Fallow	12	193	13
W-W-Pea	15	186	13
W-W-Wheat	**21**	190	13
$LSD_{(p = 0.05)}$	4	16	1

W is wheat.

The mass of LF in soil was greatest with continuous wheat, but the concentration of C and N within LF was greatest with fescue. Light fraction is a recently deposited source of organic residues that serves as a substrate for microbial activity and subsequent aggregation.

Soil microbial biomass C and potential N mineralization

Rotation	Soil microbial biomass C	Potential N mineralization
	mg · g^{-1} soil	mg · g^{-1} · 24 d^{-1}
Bromegrass	1.1	**43**
Fescue	**1.2**	30
W-W-Canola	0.9	28
W-W-Fallow	0.9	19
W-W-Pea	0.9	23
W-W-Wheat	0.9	26
$LSD_{(p = 0.05)}$	0.1	13

W is wheat.

Fescue had the highest concentration of soil microbial biomass C. Bromegrass had the highest concentration of potential N mineralization. These biologically active C and N pools are good indicators for microbial-mediated soil aggregation.

Mean-weight diameter

Rotation	Mean-weight diameter of water-stable aggregates (mm)
Bromegrass	**2.1**
Fescue	**2.2**
W-W-Canola	1.5
W-W-Fallow	1.6
W-W-Pea	1.7
W-W-Wheat	1.8
$LSD_{(p = 0.05)}$	0.4

W is wheat.

Bromegrass and fescue had the largest mean-weight diameter of water-stable aggregates. High values are indicative of strong resistance to water erosion. The permanent surface cover and lack of soil disturbance with perennial grass rotations were more effective in producing long-lasting microbial glues than with cereal rotations.

Soil organic C and total soil N

Rotation	Soil organic C	Total soil N	C:N
	mg · g^{-1} soil	mg · g^{-1} soil	g · g^{-1}
Bromegrass	**43**	3.6	12
Fescue	**45**	3.5	**13**
W-W-Canola	40	**3.9**	10
W-W-Fallow	37	**3.9**	10
W-W-Pea	37	3.8	10
W-W-Wheat	39	**3.9**	10
$LSD_{(p = 0.05)}$	5	0.1	1

W is wheat.

Bromegrass and fescue had the highest concentration of soil organic C. In contrast, highest concentration of total soil N was with cereal rotations. Perennial grass rotations were not fertilized, while cereal rotations were. Nitrogen is a necessary fertility strategy, but may have negative consequences on aggregation.

Summary and conclusions

At the end of 10 years of management:

- surface soil (0-10 cm) aggregation was at a state to resist water erosion more under perennial grass (i.e., Bromegrass and fescue) than under cereal rotations
- perennial grass systems had higher concentrations of soil organic C, light fraction, microbial biomass C, and potential N mineralization than cereal rotations
- cereal rotations had higher concentration of total soil N than perennial grass systems
- there were few significant differences in soil properties among the various cereal rotations
- relationships (r^2) between mean-weight diameter (as an estimate of erosion resistance) and biochemical soil properties were not equal:
  - LF = 0.00
  - PMN = 0.38
  - TSN = 0.77
  - SOC = 078
  - SMBC = 0.96