Climatic Influences on Active Fractions of Soil Organic Matter

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RATIONALE

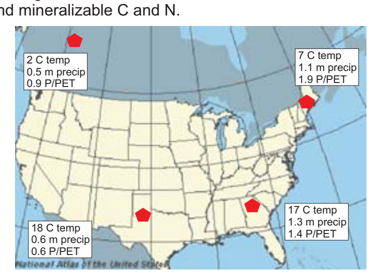
Biologically active fractions of soil are responsive to changes in management, which makes them excellent indicators of soil quality.

Although abundant information on biologically active soil fractions is available from various ecoregions in the world, synthesis of data is problematic.

Protocols for measuring soil microbial biomass and mineralizable C and N are numerous, which makes comparisons among studies unreliable.

OBJECTIVE

Assess the effects of gross climatic differences among four regions in North America on soil microbial biomass C and mineralizable C and N.



MATERIALS and METHODS

Soils

Alberta/BC (fine, montmorillonitic, frigid Typic Natriboralfs)
(fine, montmorillonitic, frigid Mollic Cryoboralfs)
(fine-loamy, mixed, frigid Typic Cryoboralfs)
0-5, 5-12.5, and 12.5-20 cm depths

Maine (coarse-silty, isotic, frigid Aquic Haplorthods)
(fine, illitic, nonacid, frigid Aeric Epiaquepts)
0-5, 5-10, and 10-20 cm depths

Texas (fine, montmorillonitic, hyperthermic Udic Pellusterts)
(fine, mixed, thermic Fluventic Ustochrepts)
(fine-loamy, siliceous, thermic Plinthic Paleudults)
(fine, mixed, thermic Udic Paleustalfs)
(fine, mixed, thermic Vertic Paleustolls)
(fine-loamy, mixed, thermic Aridic Paleustolls)
0-7.5 cm depth

Georgia (clayey, kaolinitic, thermic Typic Kanhapludults)
0-2.5, 2.5-7.5, and 7.5-15 cm depths

Management

Barley, canola, pea, wheat under conventional and no tillage in AB
Wheat, clover, bean, maize, potato, and sod in ME
Maize, sorghum, wheat, soybean, cotton with tillage, N fertilizer, cover crops, bermudagrass w/ manure rates in TX
Millet/clover, cotton/rye under conventional and no tillage in GA

C mineralization

15-120 g of oven-dried soil (45-60 C) passed through 4.75 mm
50% water-filled porosity, 25 C, titration of alkali at 3, 10, and 24 d

Soil microbial biomass C

Fumigation with $CHCl_3$ at 10 d of pre-incubation, $C_f/0.41$

Net N mineralization

Inorganic N (NO_3 + NO_2 + NH_4) at 0 and 24 d of incubation

Total organic C

Soil ball milled and analyzed with dry combustion (ME, GA) and with acid digestion (AB/BC, TX)

RESULTS and DISCUSSION

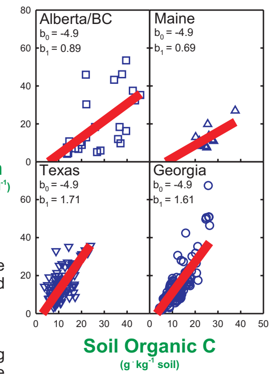
Mean soil organic C (SOC) values were:

Alberta/BC	28 ± 11 mg g^{-1} (n=24)
Maine	25 ± 5 mg g^{-1} (n=12)
Texas	11 ± 4 mg g^{-1} (n=117)
Georgia	12 ± 5 mg g^{-1} (n=131)

Lower temperature, especially in winter when it falls below a threshold for activity, limits decomposition of organic matter resulting in accumulation with time.

Fig. 1

Basal Soil Respiration ($mg\ CO_2\text{-}C \cdot kg^{-1}\ soil \cdot d^{-1}$)

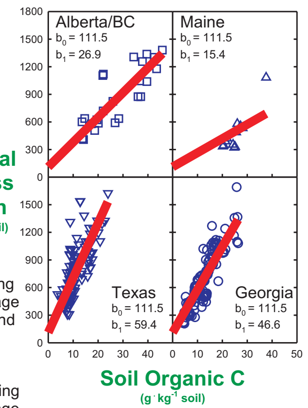


Ratio of BSR-to-SOC increased with increasing temperature (i.e., Average of 0.8 in cold climates and 1.7 in hot climates).

Ratio of BSR-to-SOC decreased with increasing precipitation (i.e., Average of 1.3 in dry climates and 1.1 in wet climates).

Fig. 2

Soil Microbial Biomass Carbon ($mg \cdot kg^{-1}$ soil)



Ratio of SMBC-to-SOC increased with increasing temperature (i.e., Average of 21 in cold climates and 53 in hot climates).

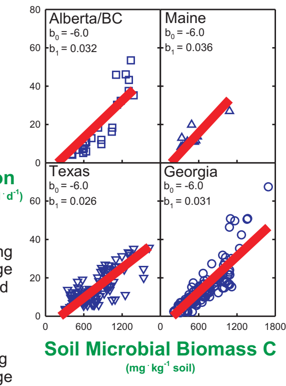
Ratio of SMBC-to-SOC decreased with increasing precipitation (i.e., Average of 43 in dry climates and 31 in wet climates).

Greater active fractions (i.e., BSR and SMBC) relative to to SOC in hotter than in colder regions may be a consequence of longer time for plant production and subsequent development of biologically active soil fractions from these substrates.

Accumulation of resistant SOC in colder regions, because of the short growing season and incomplete decomposition of residues, may be the reason that active soil C and N pools became a smaller fraction of total C compared with hotter regions.

Fig. 3

Basal Soil Respiration ($mg\ CO_2\text{-}C \cdot kg^{-1}\ soil \cdot d^{-1}$)



Ratio of BSR-to-SMBC decreased with increasing temperature (i.e., Average of 34 in cold climates and 28 in hot climates).

Ratio of BSR-to-SMBC increased with increasing precipitation (i.e., Average of 29 in dry climates and 33 in wet climates).

Table 1. Association of active soil C and N pools with soil organic C (SOC) as influenced by climatic region (n=284).

Source of variation	$CMIN_{0\text{-}3\,d}$	$CMIN_{0\text{-}24\,d}$	BSR	SMBC	$NMIN_{0\text{-}24\,d}$
Variability explained (%):					
SOC alone	26.4 ***	35.2 ***	34.7 ***	31.3 ***	15.3 ***
Hot (TX+GA) vs cold (AB+ME)	13.7 ***	21.2 ***	22.0 ***	35.9 ***	24.1 ***
Wet (ME+GA) vs dry (AB+TX)	9.4 ***	0.0	1.1 **	8.5 ***	3.5 ***
AB+GA vs ME+TX	0.8 *	0.3	0.1	0.0	4.5 ***

$CMIN_{0\text{-}3\,d}$ is the flush of CO_2-C evolved following rewetting of dried soil during 3 d of incubation ($mg \cdot kg^{-1}$ soil), $CMIN_{0\text{-}24\,d}$ is cumulative carbon mineralization during 24 d of incubation ($mg \cdot kg^{-1}$ soil), BSR is basal soil respiration ($mg \cdot kg^{-1}\ soil \cdot d^{-1}$), SMBC is soil microbial biomass carbon ($mg \cdot kg^{-1}$ soil), $NMIN_{0\text{-}24\,d}$ is net nitrogen mineralization during 24 d of incubation ($mg \cdot kg^{-1}$ soil), and SOC is soil organic carbon ($g \cdot kg^{-1}$ soil). N.D. is not determined. *, **, and *** are significant at $P \leq 0.1$, $P \leq 0.01$, and $P \leq 0.001$, respectively.

Table 2. Association of mineralizable C and N with soil microbial biomass C (SMBC) as influenced by climatic region (n=284).

Source of variation	$CMIN_{0\text{-}3\,d}$	$CMIN_{0\text{-}24\,d}$	BSR	$NMIN_{0\text{-}24\,d}$
Variability explained (%):				
SMBC alone	38.1 ***	61.5 ***	64.5 ***	30.0 ***
Hot (TX+GA) vs cold (AB+ME)	3.2 ***	1.7 ***	1.1 **	2.1 ***
Wet (ME+GA) vs dry (AB+TX)	14.5 ***	3.1 ***	0.7 **	15.3 ***
AB+GA vs ME+TX	1.1 ***	0.1	0.0	9.0 ***

$CMIN_{0\text{-}3\,d}$ is the flush of CO_2-C evolved following rewetting of dried soil during 3 d of incubation ($mg \cdot kg^{-1}$ soil), $CMIN_{0\text{-}24\,d}$ is cumulative carbon mineralization during 24 d of incubation ($mg \cdot kg^{-1}$ soil), BSR is basal soil respiration ($mg \cdot kg^{-1}\ soil \cdot d^{-1}$), $NMIN_{0\text{-}24\,d}$ is net nitrogen mineralization during 24 d of incubation ($mg \cdot kg^{-1}$ soil), and SMBC is soil microbial biomass carbon ($mg \cdot kg^{-1}$ soil). *, **, and *** are significant at $P \leq 0.1$, $P \leq 0.01$, and $P \leq 0.001$, respectively.

SUMMARY and CONCLUSIONS

Mean annual temperature had a greater influence on biological properties expressed per unit of SOC than did mean annual precipitation. Although hotter regions were not able to retain as large a portion of organic inputs as SOC compared with colder regions due to high annual decomposition rates, biologically active components of soil organic matter in hotter regions were as high per mass of soil and 2.3±0.7 times greater per unit of SOC than in colder regions.

Ratios of BSR-to-SOC and SMBC-to-SOC in wetter regions were 23±15% lower than in drier regions.

Macroclimate influenced specific activities of SMBC less (13±12% of variation) than active fractions of SOC (29±10% of variation). This implies that soil microbial biomass is much more intimately linked to soil microbial activity across major differences in climate than it is with total organic C.

Differences in climate alter the quantity of various fractions of organic matter that are less utilized by microorganisms. Colder and wetter regions had a greater pool of biologically unavailable organic matter than hotter and drier regions.

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