Tôhoku Geophys. Journ. (Sci. Rep. Tôhoku Univ., Ser. 5), Vol. 36, No. 4, pp. 539-543, 2003

Progress Toward Remote Sensing of Soil Organic Matter Quality (Extended Abstract)

DANIEL M. WHITE[1], D. SARAH GARLAND[2], CHIEN-LU PING[3] and GARY MICHAELSON[3]

[1]Corresponding author: Associate Professor of Civil and Environmental Engineering, Box 755900, Fairbanks, AK 99775-5900

[2]Research Associate, Water and Environmental Research Center, University of Alaska Fairbanks, 99775.

[3]Professor of Plant, Animal and Soil Sciences, University of Alaska Fairbanks, Agricultural and Forestry Experiment Station, 533 E. Fireweed, Palmer, AK 99645

(Received December 20, 2002)

Abstract: In the past 30 years, the arctic climate has warmed appreciably and there is evidence for a significant polar amplification of global warming in the future. A warming and drying of northern soils could result in an increase in organic matter decomposition and positive feedback to future climate warming. Northern ecosystems have accumulated 25-33% of the world's soil carbon, much of which is preserved as poorly decomposed plant remains. Soil organic matter (SOM) decomposition rate, however, depends on many variables such as temperature, nutrient availability, pH, oxidation/reduction potential, and chemical composition of the SOM. This paper addresses the effect of SOM composition on CO_2 respiration in arctic soil under substrate-limited conditions.

In previous research, the dependence of CO_2 respiration on SOM composition for arctic soils was empirically modeled for substrate-limited conditions. Soils from across the Western and Northern Alaska transects were analyzed in an attempt to tie subsurface SOM quality to cover type, a parameter that could be remotely sensed. The three cover materials studied were moist acidic tundra, moist non-acidic tundra and tussock tundra. The clearest trend observed was that SOM quality was highest in moist acidic tundra samples, followed by tussock tundra and lowest in non-acidic tundra. Results suggest that generalizations about the SOM quality in soils under different tundra types could be made.

Introduction

Northern ecosystems contain an estimated 25-33% of the world's soil carbon (Oechel & Vourlitis, 1995). Cold temperatures and/or saturated soil conditions reduce the rate of SOM decomposition in most northern soils. Until recently, the net carbon balance in northern ecosystems tended toward carbon preservation since the primary production rate exceeded the decomposition rate (Oechel & Billings, 1992). As a result of climate change, however, a warming and drying of northern soils could lead to an increase in SOM decomposition and an increase in carbon dioxide (CO_2) flux to the atmosphere. The added CO_2 could result in positive feedback to global warming. The magnitude of the CO_2 flux, however, is dependent on many biological controls on decomposition including nutrient availability, pH, temperature, oxidation-reduction potential, and the biological stability of the SOM. Since high latitude soils contain SOM that can be more

Table 1. Sampling site locations and classifications

Site number	Site name and cover class	Location (Lat. & Long.)	Soil classification
1	Council Barren Site: Nonacidic Tundra	64°43.556′W 163°56.688′	Fragmental, mixed, superactive, subgelic, Typic Cryorthent
1	Toolik Moist Acidic Tundra	68°37.459′N ; 149°37.003′W	Loamy, mixed Typic Aquiturbel
1	Toolik Moist Acidic Tundra, tussock	68°37.733′N ; 149°37.15′W	Loamy, mixed Typic Aquiturbel
2	Happy Valley-Acidic tussock tundra	69°8.783′N ; 148°51.233′W	Loamy, mixed Ruptic-Histic Aquiturbel
3	Sagwon Hills Moist Acidic Tundra	69°25.505′N ; 148°41.714″W	Ruptic-Histic Aquiturbel
3	Sagwon Hills Moist Nonacidic Tundra	69°26′46″N ; 148°40′22″W	Mollic Aquiturbel
4	Deadhorse Site: Mile 411 Dalton Highway-wet nonacidic tundra	70°16′N ; 148°53′W	Typic Aquiturbel
5	Betty Pingo, Prudhoe Bay-moist nonacidic tundra, flat polygon center	70°16.867′N ; 148°53.85′W	Euic Sapric Glacistel
6	Oumalik Moist Acidic Tundra	68°43′58.8″N ; 155°51′40″W	Coarse-silty, mixed, Ruptic-Histic Aquiturbel
6	Oumalik Moist Nonacidic Tundra	68°44′07″N ; 155°51′59.6″W.	coarse-mixed, gelic Glacic Aquiturbel
7	Ivotuk 1—Moist Acidic Tundra	68°29′14.7″N ; 155°44′22.7″W	Coarse-loamy, mixed, gelic Ruptic-Histic Aquiturbel
7	Ivotuk 3—Moist Nonacidic Tundra	68°28′43″N ; 155°43′57″W	Coarse-loamy, mixed, nonacidic pergelic Typic Molliturbel
7	Ivotuk 4 — Moist Acidic Tundra Moss Site	68°28′51″N ; 155°44′33.4″W	Loamy, mixed, acidic, Ruptic-Histic Aquiturbel
8	Mauze Creek - Tussock Tundra	65°27.126′N ; 164°37.709′W	Fine-loamy, mixed, superactive, pergelic, Ruptic-Histic Aquiturbel
9	Kougarok Tussock Tundra, Hinzman Tower Site	65°26.422′N ; 164°34.71′W	Fine-silty, mixed, superactive, subgelic, Ruptic-Histic Aquiturbel
10	Council Barren Site: Acidic Tundra	64°43.560′, W 163°56.311′	Loamy-skeletal, mixed, superactive, subgelic Aquic Dystocyept
10	Council Tundra	64°50′32.6″ N ; 163°41′39.2″W	Dysic Fluvaquentic Hemistel

than 12,000 years old (Ping *et al.*, 1996), not all SOM is equally biodegradable.

SOM can be fingerprinted using the analytical technique, pyrolysis-gas chromatography/mass spectrometry (py-GC/MS). Py-GC/MS fingerprints provide information about the molecular composition of SOM. The research presented herein relied on the central hypothesis that specific molecular components of SOM could be used to characterize its biological stability. The research built on recent studies in which py-GC/MS analysis was combined with incubation results to model the dependence of CO_2 flux on SOM quality (White *et al.*, 2002). In order to understand the potential influence of SOM quality on respiration potential, SOM quality must be predicted on a regional scale. This research tested the hypothesis that subsurface SOM quality varies with different tundra cover types and that this difference could be detected using py-GC/MS.

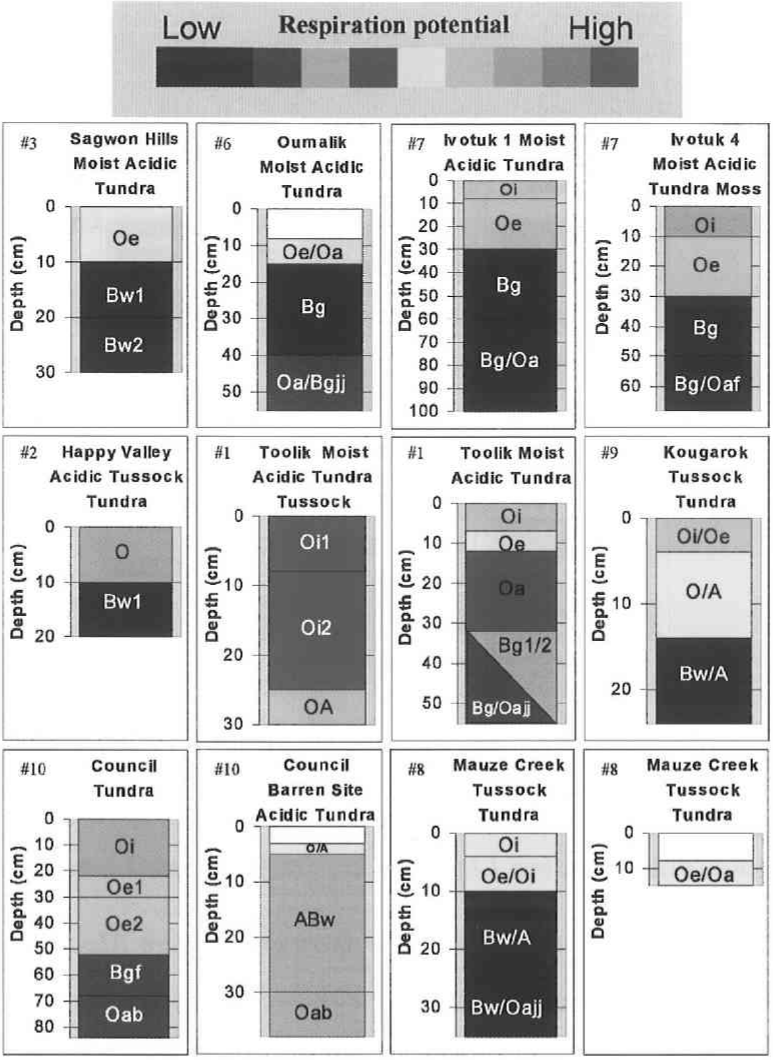

Fig. 1. Relative SOM quality at acidic and tussock tundra sites.

Materials and Methods

The location and classification of each study site is presented in Table 1. All soils were described and characterized according to Soil Survey Staff (1998). In the laboratory, samples were prepared and analyzed according to White *et al.*, (2002). The model described in White *et al.*, (2002) was used to rank each soil horizon according to its potential to produce CO_2 over the course of 70 days in an SOM-limited environment.

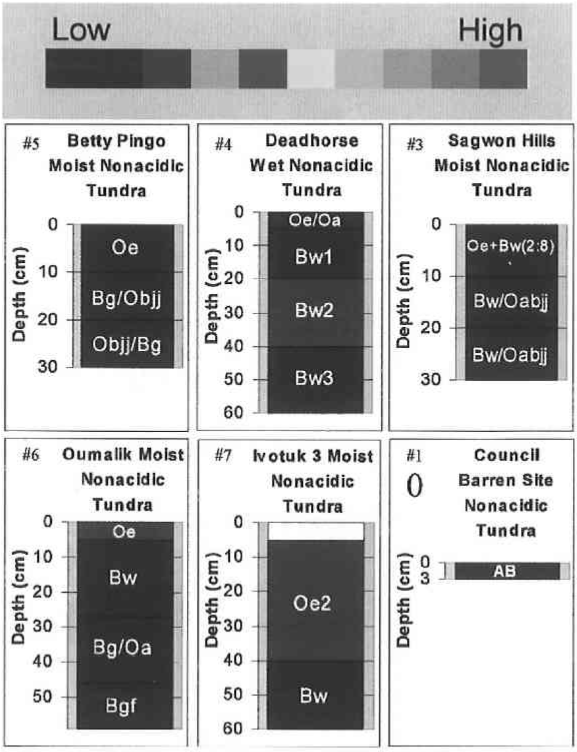

Fig. 2. Relative SOM quality at nonacidic tundra sites.

Results

Predicted SOM quality for samples on the Northern and Western Alaska transects

Moist acidic and tussock tundras

Moist acidic and tussock tundra samples typically had thick, poorly humified organic horizons containing relatively high-quality (labile) SOM. At some sites, the acidic tundra samples contained the highest quality organic matter while tussock tundra samples were of slightly lower quality. In nearly all cases, the organic matter decreased in quality with depth and with increasing mineral content. That is, organic horizons contained the most degradable organic matter followed by B and C horizons, respectively. In general, Oi horizons contained the most degradable organic matter followed by Oe and Oa horizons, respectively. Where cryoturbated horizons were found, the organic matter was generally equally or more degradable than the SOM of other soils found at the same level. In no case was an Oajj horizon of equal SOM quality to an Oa horizon. This was because humified SOM of the host B horizon contributed to the overall poor quality SOM.

Nonacidic tundras

Nonacidic tundras typically had thinner, more humified organic horizons with lower quality organic matter than the acidic tundra sites. No Oi horizon was present in any of the nonacidic tundra cores. All other O horizons, Oe and Oa were of poor quality (blue). Results indicated that in the nonacidic tundra samples, organic matter was both more humified and generally of lesser quality than in acidic or tussock tundra samples.

Applications and limitations

Data shown are based on predictions from a model relying on the relative abundance of primary polysaccharides in a suite of compounds in circumpolar soil samples. The predictions were based on incubation conditions favoring a substrate-limited environment. In other environments, where organisms are limited by low pH (moist acidic tundra), temperature, electron donors or acceptors, the substrate dependence is expected to be different and a separate model would be needed. Other limitations of the model are discussed in White *et al.*, (2002).

Conclusions

In general, SOM quality was highest in the organic horizons and generally decreased with depth, except in cryoturbated soil horizons. In general the acidic and tussock tundra samples were of highest SOM quality. The moist acidic tundra samples were of consistently higher quality than non-acidic tundras.

Acknowledgements : Thanks to IARC/CIFAR, NOAA and Alaska EPSCoR for funding of this project.

References

Oechel, W.C., and Billings, W.D., 1992 : Anticipated effects of global change on carbon balance of arctic plants and ecosystems. In : Arctic Physiological Processes in a Changing Climate (eds. Chapin III, F.S. Jeffries, R.L. Shaver, G.R. Reynolds, J.F. & Svobada, J.). 139-168. Academic Press. San Diego, CA.

Oechel, W.C., and Vourlitis, G. L., 1995 : Effect of global change on carbon storage in cold soils. In : Soils and Global Change (eds Lal, R. Kimble, J. Levine, E. & Stewart, B.A.). 117-130. Lewis Publishers. New York.

Ping, C.L., G.J. Michaelson, and J.M. Kimble., 1997 : Carbon storage along a latitudinal transect in Alaska. *Nutrient Cycling in Agroecosystems* **00**, 1-8.

Soil Survey Staff, 1998 : Keys to Soil Taxonomy, 8^{th} ed. USDA Soil Conservation Service. Washington DC.

White, D.M., D.S. Garland, X. Dai and C.-L. Ping, (*in press*), Fingerprinting soil organic matter in the Arctic to help predict CO2 flux, Cold Regions Science and Technology.