CHAPTER 47

Organic Carbon Stores in Alaska Soils

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CONTENTS

INTRODUCTION

The global soil organic matter (SOM) pool contains approximately three times as much carbon (C) as terrestrial vegetation (Schlesinger, 1995). The soil organic carbon (SOC) component of SOM is very large and generally has long residence time. In regions where SOM accumulation exceeds decomposition, SOC serves as a sink in the global C cycle. This is especially true in the Arctic and the Subarctic (Oechel et al., 1993). Natural and anthropogenic environmental changes, such as wildfire, forest harvest, cultivation, and hydrological shifts caused by climate change alter the dynamics of SOC. Decreasing the SOC pool leads to an increase in greenhouse gas input to the atmosphere. In the permafrost zone, climatic changes may have a major impact on active layer dynamics that can affect SOC fluxes. Alaska has one third of its landmass in the arctic with continuous permafrost and the rest in the boreal (subarctic) with discontinuous or sporadic permafrost.

Carbon dynamics in the Arctic has received more attention because of the integrated NSF-sponsored Land–Atmosphere–Ice Interaction study (Michaelson et al., 1996), with only limited attention paid to C stores in the rest of the state (Ping et al., 1997; Van Cleve et al., 1993). The

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vastness of the boreal forest ecosystem and its impact on C stores and C fluxes cannot be overlooked. Assessment of the impact of C flux and ecosystem changes, which may result from climate change, can only be done with a systematic estimation of C stores in all of Alaska. C stores estimated by STATSGO (Soil Survey Staff, 1996) are considerably lower than those estimated by the whole pedon approach (Michaelson et al., 1996; Ping et al., 1997). The objectives of this chapter are to: (1) summarize C-store data on a pedon basis among different ecosystems to provide a basis for a regional view of the present level of C stores in Alaska soils, and (2) summarize the patterns of C stores within soil profiles of the different ecosystems of Alaska.

MATERIALS AND METHODS

SOC Analysis

All soil organic carbon data collected in and after 1992 were described and sampled according the Soil Survey Manual (Soil Survey Division Staff, 1951, 1993) and shipped to the USDA National Soil Survey Laboratory for characterization analysis. SOC was determined by LECO combustion C analyzer for samples taken after 1989 and by the Walkley–Black chemical oxidation method (Nelson and Sommers, 1982) for samples prior to 1989. The samples were air-dried and disaggregated to pass through a 2-mm sieve. Soil organic carbon was determined after the soil sample was treated with dilute acids to remove inorganic C.

Soil C Stores

Soil organic carbon store data were obtained from published sources (Ping et al., 1997a, 1998a; Michaelson et al., 1996) or calculated from the National Soil Survey Center (NSSC) soils database for those pedons sampled prior to 1991. In many of the early samples, organic carbon contents and bulk densities of the organic horizons were not analyzed and only horizon thickness was recorded. Therefore the C stores were estimated based on the correlation between SOC and bulk density determined for soils of each region (Michaelson, G.J. et al., 1999). (Estimated bulk densities are in bold type in Appendix A.) Soil classification of pedons listed in NSSC database prior to 1997 was correlated according to the latest version of Soil Taxonomy (Soil Survey Staff, 1998). The general locations of sample sites are shown in Figure 47.1.

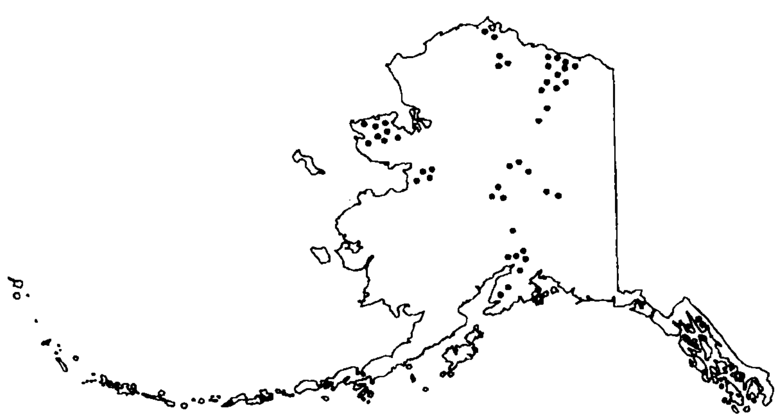

Figure 47.1 Sampling site locations.

RESULTS AND DISCUSSION

C Stores

Arctic Alaska

The organic carbon (OC) content and C stores of tundra soils vary according to genetic horizon and ecosystem; the results are summarized in Tables 47.1 through 47.5. On the coastal plain the vegetation is dominantly sedge and the dominant soils are Historthels and Histoturbels. The OC contents of soils range from 12 to 43% in the O horizons, 14 to 20% in the A horizons, and 6 to 7% in the B and Cf horizons. When partitioned between the organic and mineral horizons, 21 to 84% of the C stores are in the organic horizons and 16 to 79% in the mineral horizons. When partitioned between the active and permafrost layers, 54 to 60% of the C stores are in the active layers and 40 to 46% in the upper permafrost (Table 47.1). The difference in partitioning between the active and permafrost layers is greater than that between the organic and mineral horizons, indicating the important role of permafrost in carbon sequestration. This is the result of a physical equilibrium between the active and permafrost layers maintained by the annual freeze–thaw cycle.

In the arctic foothills, the main soil types are Aquiturbels, with organic and mineral horizon partitioning of C stores of 1 to 3; however, the partitioning between the C stores in active and permafrost layers is similar to that of the coastal plain soils. C stores in soils not affected by

Table 47.1 Carbon Storage to 1 m in Soils of Arctic Alaska Including the Seward Peninsula

Landform Great Group (n)	C Stores (range) (kg C m^{-2})	Organic Horizons (%)	Mineral Horizons (%)	Active Layer (%)	Permafrost (%)
		Arctic Coastal Plain			
Histoturbels (3)	80 (59–94)	60	40	60	40
Historthels (7)	62 (36–82)	55	45	56	44
Sapristels (4)	70 (61–78)	84	16	54	46
Aquiturbels (4)	52 (48–60)	21	79	58	42
		Arctic Foothills			
Histoturbels (2)	55 (32–78)	69	31	78	22
Sapristel (1)	70	100	0	54	46
Aquiturbels (9)	46 (16–88)	26	74	57	43
Dystrocryept (1)	3	0	100	100	0
Cryorthent (1)	4	25	75	100	0
Aquorthel (1)	30	30	70	57	43
Haplorthel (1)	10	20	80	100	0
		Arctic Seward Penninsula			
Histoturbels (2)	76 (61–91)	55	45	82	18
Historthel (1)	102	12	88	18	82
Aquiturbel (1)	94	60	40	69	31
Haplorthel (1)	52	63	37	85	15
Fibrist/Sapristel (3)	96 (81–109)	88	12	66	34

Source: Hoefle, C. et al., 1998; Michaelson, G.J. et al., 1996; Ping, C.L. et al., 1998a.

permafrost are very low, ranging from 3 to 4 kg C m^{-2}, with more than 75% in the mineral horizons. Permafrost-affected organic soil, the Sapristel, forms in deep organic matter deposit due to its landscape position; thus all of its C stores are in the organic horizons as compared with the 84% for the Sapristel on the Arctic Coastal Plain where the subsoils consist of mineral sediments. However, the Sapristels in the arctic foothills have slighter higher C stores in the permafrost layer as compared to that of the arctic coastal plain due to rising permafrost tables following the organic deposits. The partition of SOC between the organic and mineral horizons in the Arctic Seward Peninsula mineral soils is nearly equal, but between the active and permafrost layers it is 2 to 1. The C stores of the Seward Peninsula soils are higher than those of the rest of Arctic Alaska but lower in the permafrost, reflecting the lesser degree of cryoturbation and increased active layer depths due to warmer climate.

The C stores in the coastal plain mineral soils range from 36 to 94 kg C m^{-2}, with an average of 65 kg C m^{-2}; in the Arctic Seward Peninsula they range from 52 to 102 kg C m^{-2} with an average of 80 kg C m^{-2} (Hoefle et al., 1998; Michaelson et al., 1996; Tables 47.1 and 47.5.). The tundra soils on the Arctic Foothills have a wide range of C stores, from 10 to 88 kg C m^{-2} with the exception of these newly formed alluvial soils and barren ridge tops that have C stores less than 4 kg C m^{-2}. These values are 30 to 100% higher than previously reported (Billings, 1987; Chapin and Matthews, 1993; Post et al., 1982). On average, nearly half of the total C is stored in the upper permafrost, a phenomenon that indicates the importance of permafrost in carbon sequestration and is vulnerable to climate change.

Interior Alaska

In estimating C storage of Alaskan soils, Ping et al. (1997) found that values in interior Alaska range from 17 to 79 kg C m^{-2} in mineral soils and more than 130 kg C m^{-2} in organic soils. These estimates generally agree with those of Chapin and Matthews (1993) and Kimble et al. (1993). There is less cryoturbation in most interior soils compared to arctic tundra soils and most OC is concentrated near the soil surface. However, the spatial variability of OC accumulation in this setting has not been adequately defined and deserves more attention. Fire cycles and vegetation succession play a key role in SOC dynamics (Powers and Van Cleve, 1991). Van Cleve et al. (1993) have shown that the hardwood communities generate more C in surface organic horizons than spruce communities, but that the latter accumulate more C in mineral soils.

On the Tanana River floodplain near Fairbanks, Van Cleve et al. (1993) and Ping (unpublished data) measured C stores increasing from less than 0.5 kg C m^{-2} in Entisols on the youngest river terrace (stage I) to 11 kg C m^{-2} in soils under mature spruce (stage VIII). The landscape of interior Alaska is characterized by rolling hills and broad floodplains. Thus slope, aspect, and terrace age play key roles in soil formation and vegetation community development (Furbush and Schoephorster, 1977; Péwé, 1954). On the relatively warm, well drained south facing slopes, Typic Dystrocryepts are the dominant soils with C stores ranging from 6 to 88 kg C m^{-2} and an average of 44 kg C m^{-2} (Table 47.2). In these well-drained soils, OC in the litter layer recycles rapidly, thus the surface organic horizons only account for 25% of the total pedon C stores.

The north-facing slopes tend to be poorly drained due to the presence of permafrost within 50 cm of the surface with vegetation dominated by black spruce and mosses. Here the Historthels are the dominant soils with C stores ranging from 37 to 65 kg C m^{-2}, averaging 49 kg C m^{-2}. These soils have thick organic horizons containing 80% of the pedon C stores. Since the mineral horizons are mostly shallow over fractured bedrock, only 10% of the pedon C stores are in the permafrost. Aquorthels form on floodplains, terraces, and toe slopes in the boreal forest zone with permafrost rising to within 100 cm of the soil surface due to advanced stages of vegetation succession. C stores range from 14 to 48 kg C m^{-2} with an average of 35 kg C m^{-2}. In these soils, surface organic horizons contain 71% of the total pedon C, with 29% of C stores partitioned into the upper permafrost. Such an increase in C-stores in upper permafrost of these soils as compared with the