1976

Upland aspen/birch and black spruce stands and their litter and soil properties in interior Alaska

J.L. Troth

F.J. Deneke

L.M. Brown

Recommended Citation

Troth, J. L.; Deneke, F. J.; Brown, L. M. 1976. Forest Science 22(1): 33-44.

146

Dale Bartos

Upland Aspen/Birch and Black Spruce Stands and Their Litter and Soil Properties in Interior Alaska

JOHN L. TROTH

FREDERICK J. DENEKE

LLOYD M. BROWN

Abstract. This study characterizes upland forest stands in interior Alaska and compares and contrasts their organic and soil properties. Stand data are presented for tree and sapling species in three aspen/birch and four black spruce stands. Litter layers had greater mass and were more acidic beneath black spruce than beneath aspen/birch. Litter beneath aspen/birch contained higher concentrations of C, N, P, Ca, Mg, Mn, and Zn than did black spruce organic layers. Organic layer K and Fe concentrations were similar beneath the two stand groups. Total organic layer N, P, and Zn mass were similar in the two stand groups, more Ca, Mg, and Mn were present beneath hardwoods, and more K was present beneath black spruce. Extractable soil P decreased rapidly with increasing profile depth beneath aspen/birch stands, but increased with depth to a maximum at or below 15–30 cm beneath black spruce. More exchangeable bases were present near the soil surface beneath hardwoods than beneath coniferous communities. Soils beneath the two stand groups could not be consistently separated by differences in pH, percent C, percent N, or C/N ratio. Percentage soil carbon at all depths and in all stands was closely correlated with %N ($r = 0.97$) and CEC ($r = 0.98$). ***Forest Sci. 22:33–44.***

Additional key words. *Populus tremuloides, Betula papyrifera, Picea mariana,* forest floor, soil chemistry.

INTERIOR ALASKAN FORESTS cover approximately 42.4 million ha, but only 9 million ha are considered capable of commercial forest production (Hutchinson 1967). Commercial stands occur largely on well-drained, deep loess soils closely adjacent to major drainage systems. Several detailed studies on stand structure, litter, and soil properties on those sites have been reported (Van Cleve and Noonan 1971, Van Cleve and Sprague 1971, Viereck 1970), but there have been few studies in upland forest stands not located on deep loess deposits adjacent to major rivers. Many upland forest stands are presently not considered commercially productive for timber, but they are of considerable value for watershed protection and wildlife habitat.

The study reported here was conducted to provide information on upland forest stands well removed from major river

The authors are, respectively, NDEA Research Fellow, School of Forest Resources, University of Georgia, Athens, Georgia 30601; Assistant Professor of Forestry, Department of Horticulture and Forestry, Kansas State University, Manhattan, Kansas 66506; and U.S. Army Cold Region Research and Engineering Laboratory, Alaskan Division, Fairbanks, Alaska. Manuscript received July 25, 1974.

This study was sponsored by the U.S. Army Cold Region Research and Engineering Laboratory, Alaskan Division, Fairbanks, Alaska, under work unit OCE CWIS #31003, "Watershed Studies in Cold Regions." Contribution No. 542, Department of Horticulture and Forestry, Kansas Agricultural Experiment Station, Manhattan, Kansas 66506.

TABLE 1. Topographic position of upland forest stands sampled in the Caribou Creek Watershed, interior Alaska.

Stand and stand number	Aspect	Slope	Elevation
Aspen/birch:	*Degrees*	*Percent*	*Meters*
1	197	24	460
2	220	20	460
3	196	19	460
Black spruce:			
4	127	15	430
5	13	28	460
6	149	20	520
7	99	9	610

drainages. Specific objectives were (1) to quantitatively assess plant species compositions in forest stands of the Yukon-Tanana uplands of interior Alaska, (2) to characterize various physical and chemical parameters in the organic layers beneath these stands, and (3) to determine the physical and chemical nature of the soils beneath these stands. The results obtained were to serve as a baseline for future impact studies in the study area.

Study Area

The study area is in the Caribou-Poker Creeks Research Watershed located approximately 48 km north of Fairbanks. The watershed lies in the Yukon-Tanana Uplands, a semimountainous region of interior Alaska. The low mountain peaks are quite rounded and slopes are generally moderate, although steep slopes are not uncommon. The area has a continental climate characterized by annual temperature variations between –55° and 35°C (mean of –4°C), low humidity, annual precipitation of 20 to 50 cm, and annual snowfall of about 130 cm (Johnson and Hartman 1969).

Soils have developed in place from the underlying mica shist of the Birch Creek formation. A thin layer of loess covers the area, but since the loess is derived from parent material of the same formation, no boundary exists between it and residual soil parent materials (Reiger and others 1972). Soils of south-facing slopes are usually silt loams or gravelly silt loams (Typic cryochrepts, Typic cryorthents), free from permafrost. Soils of north slopes (Histic lithic cryaquepts, Histic pergelic cryaquepts) are characterized by permafrost interspersed with unfrozen loams (Rieger and others 1972).

Within this region, the most common tree species in north-slope communities is black spruce (*Picea mariana* (Mill.) B.S.P.). The forest floor under black spruce is generally a thick mat of numerous moss and lichen species. Paper birch (*Betula papyrifera* Marsh.), quaking aspen (*Populus tremuloides* Michx.), and occasional stands of mountain alder (*Alnus crispa* (Ait.) Pursh.), predominate on south-facing slopes. White spruce (*Picea glauca* (Moench) Voss) is found on south slopes and adjacent to drainages. Numerous willows (*Salix* spp.) occur as occasional understory. Valley bottoms are occupied by riparian communities of willow and arctic dwarf birch (*Betula nana* L.) and by stunted stands of black spruce and tamarack (*Larix laricina* (DuRoi) K. Koch).

Materials and Methods

Field Methods. Seven stands were selected within the Caribou Creek watershed for detailed studies of forest communities. These were chosen to include examples of the most widely distributed forest types and topographic positions found within the experimental area. Each was located within a uniform topographic site with no major discontinuities in vegetation. Stands 1, 2, and 3 were aspen/birch stands on similar topographic positions (Table 1). The remaining stands represented black spruce communities on varying topographic positions. All stands occupied mid or upper slope positions.

Community analysis. Stand species compositions were recorded in detail using procedures similar to those suggested by Cottam and Curtis (1956) and Ohmann and Ream (1971). Twenty sample points (subplots) were established within each stand on a 4 × 5 matrix with 18.3 meters between points. A border strip at least 18.3 meters wide surrounded each stand. At each sample point, percent cover of mosses, lichens, and litter was estimated in a 1 m^2 quadrat. Projected ground cover of all herbaceous and shrub species in the quadrat was also estimated.

At each point trees (stems ⩾ 8.9 cm dbh) and saplings (2.5 to < 8.9 cm dbh) were sampled by the point-centered quarter method. In black spruce stands 6 and 7, very few stems exceeded 8.9 cm dbh. In these two stands only the first stem ⩾ 2.5 cm dbh in each quadrant was recorded. Within each stand a minimum of five dominant or codominant trees were selected for height and age measurements. Age was determined by increment cores taken 30 cm above ground level.

Organic layer and soil sampling. At four systematically selected subplots within each stand, three 0.09 m^2 samples of the organic layers, down to mineral soil, were obtained. These were separated into upper and lower layers. Material from each layer was composited for each sample point after removal of roots. In black spruce communities the upper layer of living mosses and lichens and fresh litter was separated from the underlying, compacted organic humus layer (Barney and Van Cleve, 1973). In birch-aspen communities the upper 01 horizon composed of fresh L layer litter and some of the least decomposed F layer was separated from the more decomposed humus of the 02 horizon below. At two systematically located subplots, mineral-soil samples were collected from depths of 0–7.5 cm, 7.5–15 cm, 15–30 cm, and 30–45 cm.

Laboratory Methods. Organic matter. Organic-layer samples were oven dried at 70°C, weighed, and ground in a Wiley mill to pass a 1 mm mesh sieve. Samples were heated at 550°C for 4 hours to determine volatile matter content. The pH was measured electrometrically in a saturation paste. Two g of material were digested in a nitric-perchloric acid mixture for chemical analyses. Total phosphorus was measured colorimetrically. Ca, Mg, K, Fe, Mn, and Zn were determined by atomic absorption spectrophotometry, with lanthanum oxide (La_2O_3) added during Ca and Mg determinations. Total N was determined colorimetrically after a modified Kjeldahl digestion procedure (Warner and Jones 1970). Total carbon was determined using a Leco high frequency induction furnace and Automatic Carbon Determinator. Carbon recovery was maximized using methods suggested by Young and Lindbeck (1964).

Soil. Soil samples were air dried and sieved to pass a 2mm (10-mesh) screen. Particle size distribution was determined by the hydrometer method (Bouyoucos, 1951). Soil pH was measured electrometrically in a 1 : 1 soil/distilled water suspension. Total N was determined by the macro Kjeldahl method (Black and others 1965). Available P was extracted with 0.03N NH_4F + 0.025N HCl and determined colorimetrically (Black and others 1965). Cation exchange capacity was determined by ammonium saturation with neutral 1N NH_4OA_c (Black and others 1965). Exchangeable bases in the NH_4OA_c extract were determined by atomic absorption. Total carbon was determined in the same manner as for organic layer samples and considered to be equivalent to organic carbon because of soil acidity. Soils were ground to pass a 100-mesh sieve prior to carbon determination.

Statistical analysis. Frequency of occurrence in quadrats for each species in each stand was used to group stands by polythetic agglomerative clustering analysis (Orloci 1967). Results of analyses of litter and soil characteristics were subjected to analysis of variance. Differences among mean stand values at each depth for each soil and litter characteristics were tested at the .05 level of confidence with Duncan's New Multiple Range test.

Results and Discussion

Community Analysis. Agglomerative clustering analysis clearly separated the plant

TABLE 2. Stand summary data for tree species in Caribou Creek forest stands, interior Alaska.

Stand number and species	Stems per hectare	Basal area per hectare	Importance[1] value	Average dbh	Average height	Average age
	Number	*Square meters*		*Centimeters*	*Meters*	*Years*
Stand 1:						
Betula papyrifera	1621	17.69	100.0	11.7	16.4	41
B. papyrifera (SA)[2]	2342	6.20	97.4			
Picea glauca (SA)	30	0.12	2.6			
	3990	24.01				
Stand 2:						
Populus tremuloides	862	13.74	85.9	14.2	14.5	47
Betula papyrifera	57	3.31	14.1	27.2	17.4	
Populus tremuloides (SA)	400	1.51	95.8			
Betula papyrifera (SA)	5	0.02	2.1			
Picea glauca (SA)	5	0.02	2.1			
	1329	18.60				
Stand 3:						
Populus tremuloides	546	9.64	60.1	14.9	14.7	45
Betula papyrifera	329	5.54	39.9	14.7	14.7	45
Populus tremuloides (SA)	195	0.79	61.0			
Betula papyrifera (SA)	96	0.42	35.6			
Picea glauca (SA)	7	0.02	3.3			
	1173	16.41				
Stand 4:						
Picea mariana	277	2.25	75.3	10.2	9.5	62
Populus tremuloides	42	0.40	18.3	10.9	11.3	60
Betula papyrifera	12	0.17	6.4	13.5		
Picea mariana (SA)	2661	4.79	91.6			
Betula papyrifera (SA)	141	0.17	8.4			
	3133	7.78				
Stand 5:						
Picea mariana	855	8.62	100.0	11.2	10.0	172
P. mariana (SA)	870	2.42	100.0			
	1725	10.04				
Stand 6:						
Picea mariana	983	2.00	97.8	5.1	7.3	47
Betula papyrifera	12	0.02	2.2	3.3		
	995	2.02				
Stand 7:						
Picea mariana	1567	8.18	100.0	8.2	7.7	108
	1567	8.18				

[1] Importance value = average of relative frequency + relative dominance + relative density (Ohmann and Ream, 1971).

[2] (SA) denotes sapling category.

communities into coniferous and hardwood stands as expected. The first clustering cycle grouped the two black spruce communities on southeastern aspects (stands 4 and 6) and the two communities with primarily aspen overstories (stands 2 and 3). In successive cycles the birch community (stand 1) was clustered with the two aspen stands, and the additional spruce stands (5 and 7) were fused with the first two.

Data describing tree and sapling species found in each community are summarized in Table 2. The overstory of stand 1 was composed entirely of birch with good stocking and basal area. Aspen was the most important tree species in stand 2, but birch were also present. The birch occurred in scattered groups and had an average dbh of 27.2 cm, as compared to an average dbh of 14.2 cm for aspen trees. Age of the larger birch could not be accurately determined because of heart rot, but these trees were almost certainly older survivors of a past fire which gave rise to the now predominantly aspen forest. Stand 3 was dominated by aspen mixed with birch. Other than the older birch in stand 2, the dominant trees of all birch and aspen stands were about 41 to 47 years old. These stands almost certainly originated following fires. A small number of white spruce saplings were present in each stand, but succession of hardwoods by white spruce in the study area will apparently be slowed by lack of well-distributed white spruce seed trees and the unfavorable seedbed conditions by hardwood litter and established vegetation.

Black spruce was the most important overstory species in stands 4 through 7. Although birch and aspen were scattered within two of the black spruce communities, their basal area and importance values were small. Average age of individual black spruce stands varied from 43 to 172 years. The oldest black spruce community included in the study, stand 5, was located on a steep north-facing slope. The evident slow growth and low basal area typify many black spruce stands throughout the Yukon-Tanana uplands in interior Alaska.

TABLE 3. Percentage ground cover by understory and ground cover layers in aspen/birch and black spruce stands, interior Alaska.

Layer	Percentage ground cover: aspen/birch	Percentage ground cover: black spruce
Tall shrubs	21	4
Medium and low shrubs	11	33
Dwarf shrubs and herbs	28	5
Combined moss and lichen	17	85
Mosses	16	64
Lichens	1	38
Leaf and twig litter	82	11

Percent cover of tall shrubs (*Alnus* spp. and *Salix* spp.) was greater in hardwood than in conifer stands (Table 3). The most important tall shrub beneath hardwoods was *Alnus crispa*. Large clumps of this alder were frequent in hardwood stands 2 and 3, with stem diameters ranging up to 10 cm.

The medium and low shrub layer was best developed in black spruce communities (Table 3) due to the importance of several ericaceous species, particularly *Vaccinium vitis-idaea*, *V. uliginosum*, and *Ledum groenlandicum*. Viereck (1970) noted that ericaceous shrubs may form a nearly continuous layer in black spruce/sphagnum communities in interior Alaska. The most important medium and low shrubs beneath aspen and birch were *Vaccinium vitis-idaea*, *Spiraea beauverdiana*, and *Rosa acicularis*.

Total percent cover of dwarf shrub and herbaceous species was greater beneath hardwoods than beneath conifers (Table 3). Viereck (1970) also found this layer better developed under balsam poplar than beneath spruce in river bottom successional communities in interior Alaska. Most important herbaceous species in hardwood stands were the *Graminae* spp., *Cornus canadensis*, *Lycopodium complanatum*, *Linnaea borealis*, and *Epilobium angustifolium*. No herbaceous species was very frequent in the black spruce stands. The only species having a cover value of one percent of more beneath black spruce

TABLE 4. Mass and depth of organic layers beneath aspen/birch and black spruce stands in interior Alaska.

Overstory species	Organic layer		Depth	Oven-dry mass	Volatile matter
			Centimeters	*Metric tons/ha*	*Percent*
Aspen/birch	01	mean	3.2	8.2	93.6
		range	2.4–3.6	7.0–10.0	93.2–93.9
	02	mean	6.1	46.1	80.5
		range	4.9–7.3	34.8–59.9	76.2–84.9
	Total	mean	9.3	54.2	
		range	7.3–10.9	44.8–67.3	
Black spruce	upper	mean	5.7	15.0	95.1
		range	4.9–7.2	13.2–16.0	93.7–96.0
	lower	mean	12.2	78.2	84.4
		range	9.7–18.1	64.3–104.5	80.2–88.0
	Total	mean	17.9	93.2	
		range	15.1–25.3	80.3–120.3	

were *Empetrum nigrum*, *Rubus chamaemorus*, and the *Graminae*. Even these low values are likely to be high, in that occurrence in the square meter quadrat was recorded as one percent cover for that sample point.

Combined moss and lichen cover was 85 percent in coniferous communities as compared to only 17 percent beneath hardwoods (Table 3). Total cover by leaf and twig litter was 11 percent in black spruce stands and 82 percent beneath hardwoods (Table 3). *Pleurozium schreberi* was the most prominent moss species in all spruce communities. *Sphagnum* spp. were found on the steep, north-facing slope beneath stand 5. *Polytrichum* spp., *Dicranum* spp., and *Hylocomium splendens* were also frequently encountered in black spruce communities. Lichens were an important ground-cover component in all black spruce communities with species of *Cladonia*, *Cetraria*, and *Peltigera* predominating.

Although percentage occurrence of mosses and lichens was also high in hardwood stands, it was relatively unimportant. The most important moss beneath hardwoods was *Polytrichum* spp.

Permafrost Distribution. In stand 5, located on a steep, north-facing slope, permafrost occurred from 40 to 65 cm below the ground surface in mid July, 1972, at several sample points where *Sphagnum* species were important. Depth to permafrost was greater than one meter at all other points in this stand. Permafrost was not found within one meter of the ground surface in any other stands.

Organic matter Analyses. Oven-dry mass of organic layers in the three hardwood stands ranged from 44.8 to 67.3 metric tons/ha (Table 4). Van Cleve and Noonan (1971) reported average forest-floor masses of 40 and 42 metric tons/ha in birch and aspen stands, respectively, spanning a wide range of stand ages in interior Alaska. Alway and Kittredge (1933) reported litter masses varying from 9.3 to 48.2 metric tons/ha beneath aspen and birch stands in northern Minnesota. Litter depth beneath hardwood stands varied from approximately 7 to 11 cm.

Oven-dry mass of organic layers in upland black spruce communities varied from 80.3 to 120.3 metric tons/ha (Table 4). The greatest mass was encountered in stand 5, where organic layer depth averaged 25.3 cm. This stand was located on a relatively steep north slope and was the oldest stand included in the study. Depth of organic layers averaged approximately 15 cm in each of the other black spruce stands. Vol-

TABLE 5. Chemical properties of organic matter in upland forest stands, interior Alaska.[1]

Element and organic layer	Stand and stand number: Aspen/birch 1	2	3	Black spruce 4	5	6	7	F. 05 =
pH								
Layer 1	5.1 b	5.2 b	5.4 a	4.0 cd	3.9 d	4.2 c	4.0 cd	115.65**
Layer 2	4.3 b	4.6 a	4.8 a	3.7 cd	3.3 e	3.7 cd	3.5 de	49.21**
Percent volatile								
Carbon								
Layer 1	49.4 a	49.6 a	51.1 a	45.4 b	46.7 b	47.2 b	45.8 b	11.36**
Layer 2	51.3 a	50.7 a	49.5 ab	49.4 ab	46.9 b	48.9 ab	48.7 ab	2.89*
Percent ovendry								
Nitrogen								
Layer 1	2.34 a	2.16 a	1.90 ab	1.05 c	1.28 c	1.41 bc	1.11 c	8.55**
Layer 2	2.17 a	2.16 a	2.40 a	1.08 c	1.05 c	1.57 b	1.13 c	21.11**
C/N ratio								
Layer 1	20.1 d	22.7 cd	26.6 bcd	40.8 a	35.7 ab	32.1 abcd	39.9 a	7.01**
Layer 2	19.2 c	20.2 bc	16.8 c	36.9 a	38.9 a	26.8 b	36.0 a	16.64**
Percent ovendry weight								
Phosphorus								
Layer 1	0.14 a	0.15 a	0.14 a	0.09 b	0.06 b	0.09 b	0.08 b	19.39**
Layer 2	0.14 bc	0.18 a	0.20 a	0.15 b	0.09 e	0.11 de	0.12 cd	18.67**
Potassium								
Layer 1	0.20	0.25	0.20	0.20	0.21	0.21	0.28	0.93NS
Layer 2	0.23 a	0.24 a	0.24 a	0.21ab	0.17 bc	0.16 c	0.17 bc	6.41**
Calcium								
Layer 1	0.94 c	1.18 b	1.55 a	0.34 d	0.31 d	0.33 d	0.25 d	51.34**
Layer 2	0.49 c	0.69 b	0.96 a	0.21 d	0.15 d	0.24 d	0.16 d	63.85**
Magnesium								
Layer 1	0.27 a	0.22 b	0.20 b	0.07 c	0.06 c	0.09 c	0.08 c	64.19**
Layer 2	0.21 a	0.15 b	0.20 a	0.11 bc	0.08 c	0.10 c	0.12 bc	11.41**
Iron								
Layer 1	0.08	0.08	0.28	0.20	0.12	0.10	0.17	0.95NS
Layer 2	0.84	0.44	0.73	0.70	0.47	0.57	0.73	2.27NS
Manganese								
Layer 1	0.22 a	0.12 b	0.09 bc	0.06 c	0.06 c	0.08 bc	0.05 c	11.07**
Layer 2	0.16 a	0.11 a	0.13 a	0.02 b	0.01 b	0.02 b	0.02 b	9.63**
Zinc								
Layer 1	0.012 a	0.011 a	0.012 a	0.003 b	0.003 b	0.003 b	0.003 b	19.76**
Layer 2	0.005 ab	0.005 ab	0.006 ab	0.002 cd	0.002 cd	0.004 abc	0.003 bcd	5.49**

[1] NS = Not significant, * = significant at 0.05 level, ** = significant at 0.01 level or higher. Like letters indicate no significant differences between stands using Duncans NMRT calculated values at the 0.05 level.

atile matter contents were similar in organic layers beneath aspen/birch and black spruce.

The pH of organic layers was significantly lower in black spruce stands than beneath aspen and birch (Table 5). Litter was more acidic beneath the birch than beneath aspen-dominated stands. Lower-

TABLE 6. Mass of nutrient elements in organic layers beneath upland forest communities, interior Alaska.

				(Kg/ha)					
Stand	N	P	K	Ca	Mg	Fe	Mn	Zn	Total
Aspen/birch									
1	1470	96	152	262	145	512	112	4	2753
2	970	79	109	358	73	162	50	3	1804
3	1180	99	121	526	102	323	61	4	2416
x̄	1207	91	127	382	107	332	74	3.7	2324
Black spruce									
4	860	112	165	190	81	482	19	2	1911
5	1300	101	196	207	92	513	23	2	2434
6	1390	89	147	223	85	434	27	3	2398
7	970	81	199	180	85	345	32	3	1895
x̄	1130	96	177	200	86	444	25	2.5	2160

layer samples were more acidic than upper layer samples in all stands.

Total carbon, as percent of volatile matter, and percent nitrogen were significantly higher in organic layers from each hardwood stand than in organic layers from black spruce stands (Table 5). Statistical analysis showed a significant increase in percent C in the lower layer in black spruce stands, but no difference between layers over the three hardwood stands. Nitrogen concentrations found in hardwood litter layers were higher than those reported in other birch and aspen stands in interior Alaska (Van Cleve and Noonan 1971). Alway and Kittredge (1933) reported N concentrations in aspen and birch litter in northern Minnesota similar to those found in this study when levels are expressed as a percent of volatile matter. Similar N concentrations have also been reported in forest floors of birch stands with grass in Russia (Rodin and Bazilevich 1965). Grasses characteristically have high concentrations of mineral elements, including N (Rodin and Bazilevich 1965). Nitrogen concentrations encountered in birch and aspen litter in the current study may have been increased by the frequent presence of alders and grasses. In all stands, N levels did not differ statistically between organic layers.

C/N ratios were significantly lower in organic layers beneath hardwood stands than in organic layers beneath conifers (Table 5). C/N ratios beneath hardwoods varied from 20.1 to 26.6 in the upper litter layer and from 16.8 to 20.2 in the lower layer. Ratios ranged from 32.1 to 40.8 in the upper organic layer of black spruce stands and from 26.8 to 38.9 in the lower organic layer.

Phosphorus concentrations were significantly greater in organic layers beneath hardwood stands than in organic layers beneath spruce stands. Phosphorus levels were greater in the lower layer than in the upper layer of all stands except the birch stand, stand 1, in which no difference was found between layers.

Concentrations of all cations determined, except potassium and iron, were generally higher in organic layers beneath hardwoods than under black spruce. Concentrations of Mg and Mn were highest in litter from the birch stand (stand 1), whereas Ca concentrations were highest in litter from the two aspen stands (stands 2 and 3). Differences between Ca and Mn levels in birch and aspen litter corresponded to those reported by Van Cleve and Noonan (1971). However, Ca concentrations in birch and aspen litter were considerably lower than encountered by Van Cleve and Noonan

TABLE 7. Physical and chemical properties of soils beneath upland forest stands, interior Alaska.[1]

Element and profile depth (cm)	Stand and stand number							
	Aspen/birch			Black spruce				
	1	2	3	4	5	6	7	F.05 =
pH								
0–7.5	4.4 ab	4.6 ab	4.7 a	4.5 ab	3.8 c	4.3 b	4.6 ab	9.04**
7.5–15	4.5 c	4.8 b	4.9 b	5.2 a	4.2 d	4.6 c	5.1 a	43.84**
15–30	4.9 bc	4.9 bc	5.1 ab	5.5 a	4.6 c	4.9 bc	5.4 a	5.78*
30–45	5.1 bc	5.2 bc	5.2 bc	5.4 ab	4.9 c	4.9 c	5.6 a	6.55*
C/N ratio								
0–7.5	22.2 ab	13.3 c	16.2 bc	19.1 bc	27.4 a	20.8 ab	17.4 bc	5.44**
7.5–15	16.7	11.5	13.1	14.3	14.6	20.2	17.8	3.05NS
15–30	13.9	11.0	13.8	8.0	11.4	13.1	14.2	0.83NS
30–45	15.4	10.9	12.7	11.5	14.9	11.4	6.5	1.28NS
	Percent							
Organic carbon								
0–7.5	7.2 bc	5.2 c	4.3 c	2.2 c	18.4 a	10.9 b	3.2 c	14.77**
7.5–15	2.8	1.4	0.9	1.1	2.9	3.7	1.9	1.81NS
15–30	1.9	0.8	0.8	0.4	2.1	1.1	1.1	1.80NS
30–45	1.6	0.6	0.7	0.6	1.7	0.8	0.3	2.93NS
Total Nitrogen								
0–7.5	0.32 cd	0.39 bc	0.26 cde	0.11 e	0.67 a	0.52 ab	0.18 de	16.36**
7.5–15	0.16	0.11	0.06	0.08	0.20	0.18	0.11	2.04NS
15–30	0.14 b	0.07 c	0.06 c	0.04 c	0.18 a	0.09 c	0.08 c	14.36**
30–45	0.11 a	0.06 b	0.05 b	0.05 b	0.11 a	0.07 ab	0.05 b	4.30*
	ppm							
Extractable Phosphorus								
0–7.5	4.5 b	37.3 a	59.5 a	2.8 b	6.7 b	1.7 b	4.7 b	7.50**
7.5–15	4.4	5.6	9.2	6.0	10.2	5.5	3.0	1.67NS
15–30	5.1 bc	5.5 bc	7.2 bc	13.3 a	13.9 a	9.4 ab	3.4 c	7.51**
30–45	4.6	4.3	7.2	9.7	20.8	6.0	11.6	3.65NS
	meq/100 g							
Cation Exchange Capacity								
0–7.5	33.4 bc	31.9 bc	26.8 c	19.4 c	65.9 a	48.0 b	20.5 c	11.14**
7.5–15	26.4	16.8	12.8	11.7	17.6	22.1	14.7	1.98NS
15–30	16.1	16.1	11.1	8.0	14.0	12.3	13.1	2.50NS
30–45	17.0	14.8	10.7	8.4	15.0	11.3	8.4	2.20NS
Calcium								
0–7.5	2.6 a	2.1 a	2.7 a	0.7 bc	0.4 c	1.7 ab	0.3 c	8.98**
7.5–15	1.5 a	0.8 b	0.8 b	0.4 b	0.2 b	0.7 b	0.2 b	5.81*
15–30	1.4 a	0.8 ab	0.9 ab	0.7 ab	0.2 b	0.4 b	0.3 b	4.11*
30–45	1.5	1.1	1.1	0.6	0.2	0.4	1.1	1.69NS
Magnesium								
0–7.5	0.7 bc	0.7 bc	1.2 a	0.3 cd	0.3 cd	0.8 b	0.1 d	12.11**
7.5–15	0.3 ab	0.3 ab	0.4 a	0.2 abc	0.1 bc	0.3 ab	0.1 c	4.22**
15–30	0.4	0.4	0.4	0.3	0.1	0.1	0.1	2.16NS
30–45	0.5	0.5	0.5	0.3	0.1	0.1	0.3	1.05NS

TABLE 7—Continued.

Element and profile depth (cm)	Stand and stand number							F. 05 =
	Aspen/birch			Black spruce				
	1	2	3	4	5	6	7	
Potassium								
0–7.5	0.23 bc	0.46 a	0.48 a	0.12 c	0.33 ab	0.21 bc	0.08 c	9.93**
7.5–15	0.13	0.08	0.16	0.09	0.06	0.09	0.05	2.75NS
15–30	0.11 a	0.11 a	0.09 ab	0.06 bc	0.06 bc	0.05 c	0.05 c	12.83**
30–45	0.13 a	0.08 ab	0.07 b	0.07 b	0.06 b	0.05 b	0.05 b	6.41*
	Percent							
CaMgK Base Saturation								
0–7.5	10.2 b	10.7 abc	16.6 a	5.4 bc	1.5 c	5.6 bc	2.4 c	8.60**
7.5–15	7.4 ab	8.2 ab	10.5 a	5.5 bc	1.9 c	4.7 bc	2.2 c	7.05*
15–30	11.5	7.6	12.7	12.9	2.3	4.4	3.2	2.84NS
30–45	11.9	10.4	15.2	13.5	2.5	4.8	17.7	1.42NS

[1] NS = Not significant, * = significant at 0.05 level, ** = significant at 0.01 level or higher. Like letters indicate no significant differences between stands using Duncans NMRT calculated values at the 0.05 level.

(1971), possibly because of differences in soil types.

Mass of N, P, and Zn in organic layers was similar beneath hardwood and coniferous stands despite differences in total mass of layers (Table 6). Mass of Ca, Mg, and Mn in organic layers was higher beneath hardwood stands than beneath black spruce stands. Mass of Ca was highest beneath the two aspen stands. Mass of Mn was much higher in organic layers beneath the birch stand (stand 1) than in organic layers beneath either stand dominated by aspen. Total mass of Mg was markedly higher beneath the birch in stand 1 than beneath any other stand. Only K and Fe had a greater mass in organic layers beneath black spruce than in organic material beneath hardwoods.

The open nature of black spruce communities indicated that the character of organic layers was strongly influenced by the moss and lichen species present. Barney and Van Cleve (1973) found that organic layers accounted for 78 percent of total biomass in one interior Alaska upland black spruce stand. Litter layers beneath aspen and birch were composed largely of organic debris from the overhead tree species in the current study.

Soil Analysis. Soil properties are summarized in Table 7. All soils were either loams or silt loams. Silt plus clay content of most samples varied between 65 and 85 percent, with highest values generally found in the surface layer. No evidence of illuvial clay accumulation was found in any stand.

Soils were moderately to strongly acidic beneath all stands. Soil pH values did not consistently differ when conifer and hardwood stands were compared. The most acidic soils were beneath the oldest black spruce stand (stand 5), where pH of the surface layer was 3.8. Soil pH increased with depth beneath all stands.

Except for the surface layer, soil carbon levels did not differ significantly between hardwood and black spruce communities. Hardwood and coniferous communities could not be consistently separated on the basis of soil carbon and nitrogen. Levels of both elements were closely correlated ($r = 0.97$) and generally decreased down to the 30-cm depth beneath all stands.

C/N ratios did not differ consistently between the two stand groups.

Extractable P increased with soil depth beneath black spruce stands. Highest levels were found at or below 15–30 cm. In contrast, highest levels of extractable P were found near the soil surface in aspen-dominated stands 2 and 3. Levels of extractable P were similar at all depths beneath the birch stand. Extractable soil P was not correlated with organic carbon levels beneath either hardwood or black spruce.

Observed differences in profile distribution of soil P may reflect differences in P release from decaying organic layers and in P uptake beneath different plant communities. Beneath black spruce, extractable P had apparently accumulated at lower depths due to illuviation and lack of plant removal. Soil temperatures beneath these stands in interior Alaska are sharply lowered by thickened organic layers (Heilman 1966). Reduced soil temperatures may reduce P uptake from lower, colder soil depths by reducing root activity and by reducing development of fine roots in the lower part of the profile. Differences in rooting patterns beneath the two stand groups were not investigated, but may explain P accumulation at lower soil depths beneath black spruce. Low extractable P levels near the soil surface may result from both slow release of P from organic layers and concentration of fine absorbing roots near the soil surface. High extractable P contents near the soil surface in aspen stands indicate rapid release of easily mineralized organic P compounds from litter layers.

Cation Exchange Capacity (CEC) in all stands and depths was closely correlated with amount of organic C ($r = 0.98$). Since clay content of all soils was similar, variations in CEC were primarily determined by differences in amount of incorporated organic matter.

Surface layer soils beneath hardwood stands generally contained higher levels of exchangeable Ca, Mg, and K and had greater percentage base saturation than did soils in black spruce stands. These results indicate that larger quantities of these elements are returned to the soil surface from aspen and birch litter than from black spruce organic layers.

Conclusions

Within a forested upland watershed in interior Alaska organic layer and soil properties differed significantly beneath hardwood and black spruce stands located on uniform parent material. Differences in organic layer characteristics were consistent in each stand studied despite inclusion of black spruce stands from a variety of topographic positions. Organic layers beneath black spruce had greater thickness and mass, lower pH, and lower concentrations of N, P, Ca, Mg, Mn, and Zn than did those beneath birch and aspen. K and Fe concentrations were similar in organic layers beneath the two stand groups. Higher pH, greater nutrient element concentrations, and lower C/N ratios of hardwood organic layers indicate more favorable conditions for microbial decomposition and more rapid return of nutrients to the soil hardwood organic layers than from those beneath black spruce.

Soils beneath hardwood and black spruce stands differed in profile distribution of extractable P and in content of exchangeable cations. Highest levels of extractable P were found near the soil surface in aspen-dominated stands. Beneath black spruce extractable P levels were low near the soil surface, but increased with depth. Profile distribution of P beneath black spruce indicates slow release from organic layers and reduced removal by plant roots below 15 cm. Beneath hardwoods more exchangeable bases were present near the soil surface than beneath black spruce, further indicating a more rapid return of nutrient elements to the soil surface from aspen and birch litter than from black spruce organic layers.

Literature Cited

ALWAY, F. J., and J. KITTREDGE, JR. 1933. The forest floor under stands of aspen and paper birch. Soil Sci 35:307–312.

BARNEY, R. J., and K. VAN CLEVE. 1973. Black spruce fuel weights and biomass in two interior Alaska stands. Can J. For Res 3:304–311.

BLACK, C. A., D. D. EVANS, J. L. WHITE, L. E. ENSMINGER, and F. E. CLARK (eds). 1965. Methods of soil analysis. Part II. Chemical and microbiological properties. American Society of Agronomy, Madison, Wisconsin, Agronomy No. 9, 1572 p.

BOUYOUCOS, G. J. 1951. A recalibration of the hydrometer method for making mechanical analysis of soils. Agron J 43:434–438.

COTTAM, G., and F. T. CURTIS. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451–460.

HEILMAN, P. E. 1966. Change in distribution and availability of nitrogen with forest succession on north slopes in interior Alaska. Ecology 47:825–831.

HUTCHISON, O. K. 1967. Alaska's forest resource. USDA Forest Serv Res Bull PNW-19, 74 p.

JOHNSON, P. R., and C. W. HARTMAN. 1969. Environmental atlas of Alaska. Institute of Environmental Engineering and Institute of Water Resources, College, Alaska. 22 p.

OHMANN, L. F., and R. R. REAM. 1971. Wilderness ecology: a method of sampling and summarizing data for plant community classification. USDA Forest Serv Res Pap NC-49, 14 p.

ORLOCI, L. 1967. An agglomerative method for classification of plant communities. J Ecol 55:193–205.

RIEGER, S., C. E. FURBUSH, D. B. SCHOEPHORSTER, H. SUMMERFIELD, JR, and L. C. GEIGER. 1972. Soils of the Caribou-Pokers Creek Research Watershed, interior Alaska. US Army, Cold Reg Res Eng Lab Tech Rep 236, 10 pp.

RODIN, L. E., and N. I. BAZILEVICH. 1965. Production and mineral cycling in terrestrial vegetation. First English edition published 1967. Oliver and Boyd, London.

VAN CLEVE, K., and L. L. NOONAN. 1971. Physical and chemical properties of the forest floor in birch and aspen stands in interior Alaska. Soil Sci Soc Am Proc 35:356–360.

VAN CLEVE, K., and D. SPRAGUE. 1971. Respiration rates in the forest floor of birch and aspen stands in interior Alaska. Arctic and Alpine Res 3:17–26.

VIERECK, L. A. 1970. Forest succession and soil development adjacent to the Chena River in interior Alaska. Arctic and Alpine Res 2: 1–26.

WARNER, M. H., and J. B. JONES, JR. 1970. A rapid method for nitrogen determination in plant tissue. Soil Sci and Plant Anal 1:109–114.

YOUNG, J. L., and M. R. LINDBECK. 1964. Carbon determinations in soils and organic materials with a high frequency induction furnace. Soil Sci Soc Am Proc 28:377–381.