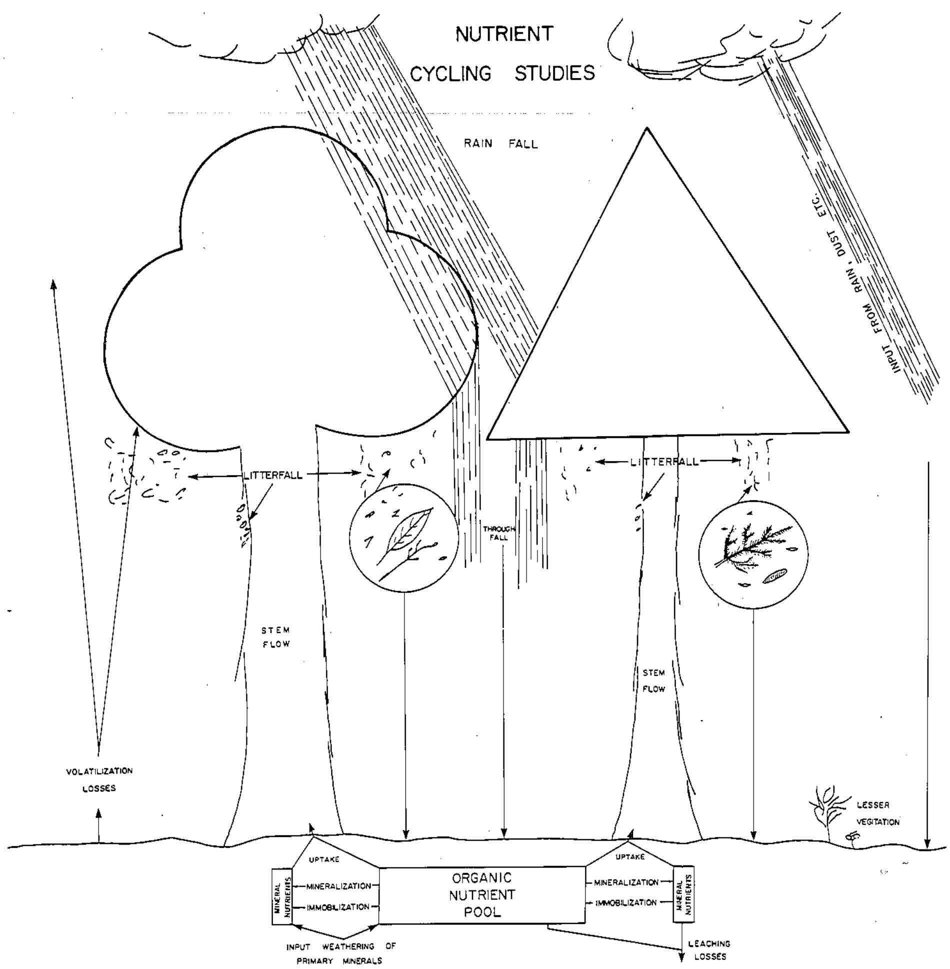

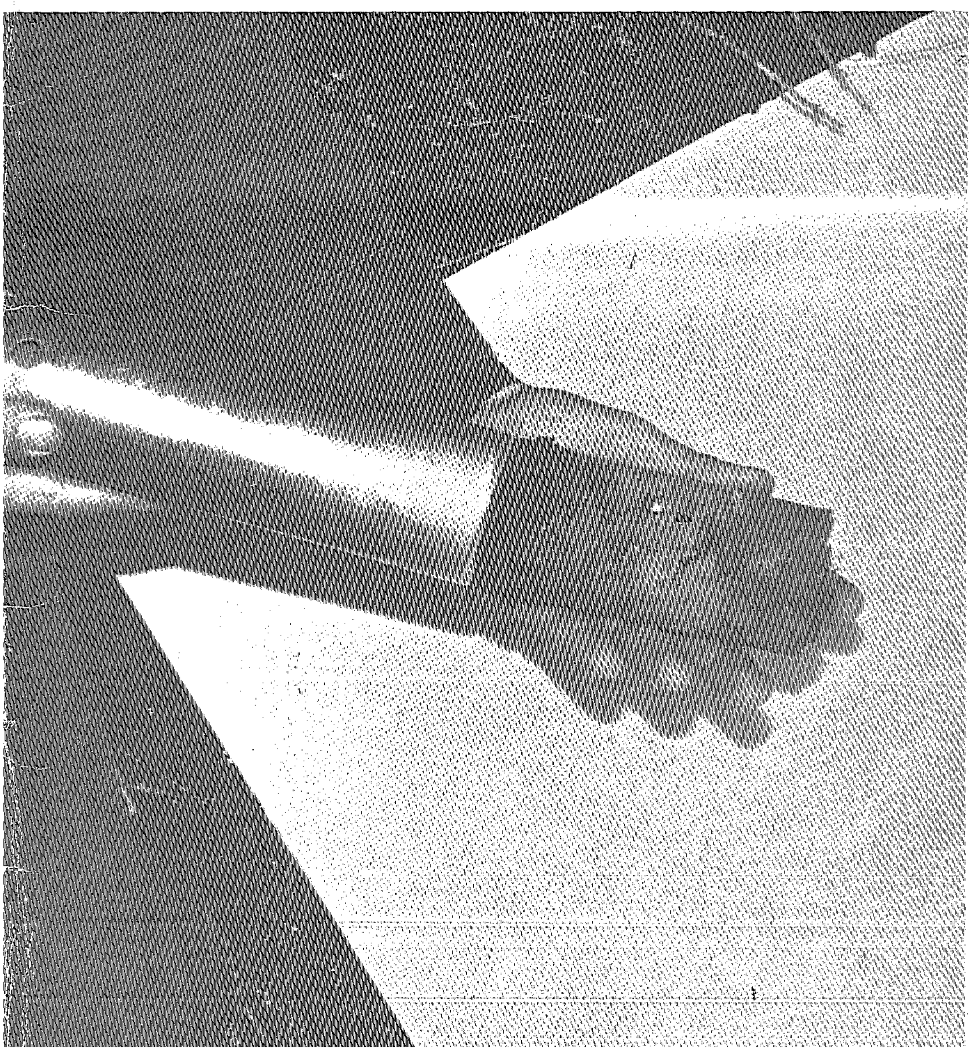

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NUTRIENT CYCLING STUDIES AT THE ACADIA FOREST EXPERIMENT STATION: ESTABLISHMENT AND SOIL CHARACTERISTICS

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MARITIMES

CANADIAN FORESTRY SERVICE

MARITIMES FOREST RESEARCH CENTRE

The Maritimes Forest Research Centre (MFRC) is one of six regional establishments of the Canadian Forestry Service, within Environment Canada. The Centre conducts a program of work directed toward the solution of major forestry problems and the development of more effective forest management techniques for use in the Maritime Provinces.

The program consists of two major elements - research and development, and technical and information services. Most research and development work is undertaken in direct response to the needs of forest management agencies, with the aim of improving the protection, growth, and value of the region's forest resource for a variety of consumptive and non-consumptive uses; studies are often carried out jointly with provincial governments and industry. The Centre's technical and information services are designed to bring research results to the attention of potential users, to demonstrate new and improved forest management techniques, to assist management agencies in solving day-to-day problems, and to keep the public fully informed on the work of the Maritimes Forest Research Centre.

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Fredericton, New Brunswick

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ABSTRACT

Organic and inorganic soil horizons under three hardwood and six softwood stands at Acadia Forest Experiment Station, New Brunswick, used for nutrient cycling studies were characterized as to their physical and chemical properties. The organic horizons were characterized in terms of their thickness and weight and the quantity of nutrient reserves in both the organic and inorganic horizons were calculated on volume and weight basis. The relationship between nutrient (nitrogen in particular) levels in the foliage, and litterfall, and those in the organic horizons was determined to characterize the rates of nutrient and organic matter turnover in different stands.

The results show no distinct differences between the thickness and weights of the organic horizons under hardwoods and softwoods. With one exception, the spruce stands have the thickest organic horizons, followed by the hardwoods and pines. The larch stand, where there is a luxurient growth of sphagnum mosses, has a thick organic horizon that cannot be separated into L, F, and H horizons. With the exception of the aspen stand, the weights of the organic horizons under these stands followed the same order as their thickness.

On a volume basis, the size of the nutrient reserves of the organic horizons shows some of the basic differences between the species sampled. Levels of nitrogen in the organic

RESUME

Des horizons de sols organiques et inorganiques sous-jacents à trois peuplements de feuillus et six peuplements de résineux de la Forêt expérimentale d'Acadia au Nouveau-Brunswick, utilisés dans des études du cycle nutritif, ont été caractérisés quant à leurs propriétés physiques et chimiques. Les horizons organiques furent caractérisés en termes d'épaisseur et de poids et la quantité des réserves nutritives des deux genres de sols, organiques et inorganiques, fut calculée selon le volume et le poids. Le rapport entre les niveaux de l'agent nutritif (l'azote en particulier) dans le feuillage, la litière et les horizons organiques fut déterminé afin de caractériser les niveaux de retournage (turnover) des agents nutritifs et des matières organiques dans les divers peuplements.

Les résultats n'indiquent aucune différence distincte entre l'épaisseur et le poids des horizons organiques sous-jacents aux feuillus et aux résineux. A une exception près, les peuplements d'Epinette possèdent les horizons organiques les plus épais, suivis des feuillus et du Pin. Le peuplement de Mélèze, où croissent des mousses de sphaigne luxuriantes, repose sur un horizon organique épais qui ne peut se séparer en catégories L, F, et H. Sauf pour le peuplement de Peuplier, les poids des horizons organiques sous ces peuplements suivaient le même ordre que leur épaisseur.

horizons under hardwoods increase, relative to the litterfall materials, faster than those of softwoods. This is a result of faster litterfall decomposition under the hardwoods.

Low coefficients of variation for the data on thickness and weights of the organic horizons indicate that collecting up to 60-120 core samples per plot within a short period is sufficient to reduce the possible error of estimate to about 10-15%.

The size of nitrogen reserves in the mineral horizons is considerably larger than that of organic horizons under all the stands.

En volume, la dimension des réserves en éléments nutritifs des horizons organiques montre certaines des différences fondamentales entre les espèces échantillonnées. Les niveaux d'azote dans les horizons organiques sous-jacents aux feuillus augmentent, relativement aux matières de la litière, plus rapidement que ceux sous-jacents aux résineux, à cause de la décomposition plus rapide de la litière sous les feuillus.

Des coefficients peu élevés de variation dans les données sur l'épaisseur et les poids des horizons organiques indiquent que la collecte de 60 à 120 carottages d'échantillon par placette suffit à réduire à environ 10 à 15% la possibilité d'erreurs dans les estimations.

La dimension des réserves d'azote dans les horizons minéraux est considérablement supérieure à celle des horizons organiques sous-jacents à tous les peuplements.

INTRODUCTION

Differential stand and soil responses were observed in a black spruce stand treated with different levels of urea and triple superphosphate in a factorial combination of fertilizer treatments (Mahendrappa 1978, Mahendrappa and Ogden 1973). Microbiological and nitrogen mineralization studies were carried out (Salonius and Mahendrappa 1975, 1979) to help explain these observed responses. Data were gathered on the various pathways and processes of nutrient cycling in six softwood and three hardwood stands of trees growing on similar soils at the Acadia Forest Experiment Station in central New Brunswick.

The size of the nutrient reservoirs in organic and mineral horizons and the physical and chemical characteristics of the soil medium, among other factors, determine the growth of trees. In turn, the trees may alter the patterns of nutrient dynamics and also the physical and chemical characteristics of the soil (Stone 1975; Turner and Singer 1976; Turner et al. 1976). Stone (1975) pointed out the complexity of the inter-relationship between forests and soil and the need to understand the various pathways and processes of nutrient cycling.

At present there is an urgent need for information on the various aspects of nutrient cycling in forest stands. Growth responses, positive or otherwise, of forest stands to fertilizer treatments are directly related to the pathways and processes of the nutrient cycle and, in general, to the rate of nutrient turnover in each stand. Potential lake and stream pollution resulting from the improper use of fertilizers can be avoided if the pathways that the fertilizer nutrients follow are known. A large number of watershed management studies have been initiated to study such processes.

Chemical composition of stemflow and throughfall samples is a function of the foliar nutrient levels and the chemical properties of incident precipitation. Precipitation chemistry is directly related to the replenishment of nutrients, nitrogen in particular, in the soil. Acid rain resulting from a point source of SO_2 or from long-range transport of air-pollutants (LRTAP) can alter the chemistry of stemflow and throughfall liquid and further degrade poor soils.

Increased interest in using the forest biomass for energy production has raised several questions that can be answered only through an understanding of nutrient cycling processes. Attempts to reduce the rotation period through tree breeding or by using coppice growth may result in an increased rate of depletion of nutrients from the soil. Utilization of the complete tree also has a similar effect and, under certain conditions, it may not be advisable to practice or implement a complete-tree utilization program.

Trees depend on the organic and mineral soil for their anchoring support and also for nutrition. Thus, the nutrient pool or reservoir in the soil constitutes an important component of nutrient cycling. Under forest stands of different species, organic horizons of varying thicknesses develop over the mineral horizons. These organic horizons exert a major influence on the growth and development of the stands and also on the nature of regeneration after clearcutting of the existing stand. Various micro- and macrobiological activities in the organic and mineral horizons keep the nutrient pool in a dynamic state. Such activities differ between stands and thus result in large variations in the size and nature of the nutrient reserve. Therefore, an effort was made to define the nature of organic and inorganic soil horizons and the nutrients in them.

This report describes the physical and chemical characteristics of organic and inorganic horizons under different stands at the Acadia Forest Experiment Station, the selection and establishment of plots in different stands, and the treatment incorporated in the studies. It is the first in a series of reports on the nutrient cycling characteristics of these stands.

MATERIALS AND METHODS

Establishment

During 1971, collection and analyses of litterfall, stemflow, and throughfall were initiated in nine stands of different tree species at the Acadia Forest Experiment Station. Two circular plots were set up in each stand and foliar samples were collected and analyzed annually. At the same time, measurements were made to characterize each stand and to estimate site quality by describing the soil profiles. During the spring of 1976, fertilization treatment with urea was included in the study. Hence, to have duplicates of control and treated plots, two additional plots were established in each stand. One of the new and one of the old plots received urea at a rate of 225 kg N ha^{-1} and the number of litterfall and throughfall collectors was increased. Locations of the sample stands at the Acadia Forest Experiment Station are presented in Fig. 1. For further information on size and location of the plots in each stand see Table 1. The numbers and types of collection systems set up in each plot of each stand are listed in Table 2.

Soil Characterization

Soil and site characterization was carried out in three stages. First, two pits were dug in each stand to determine the subgroups of the soils by identifying the different horizons on the basis of color and texture. Second, efforts were made to determine the thickness and weights of the organic (L, F, and H) horizons. Simultaneously, samples of organic and mineral horizons were collected for chemical analysis in the laboratory. Finally, numerous organic and mineral soil samples were collected from each plot for detailed determination of the nutrient levels. All data given in this report concern baseline measurements on control plots which were not fertilized.

Profile description

(i) In each stand at least two soil pits were dug either to the bottom of the root zone, until an indurated layer was reached, or until the transition from B to C horizon was recognized. In the field, the thickness of the mineral horizons and their color (using Munsell soil color chart) were determined. Samples of both organic and mineral horizons were collected for chemical analyses. From each plot at least four sods of organic horizons, 900 cm^2 (1 sq ft) were collected to determine the weight and thickness of the organic materials. Mineral soil samples were subjected to mechanical analysis, determinations of cation exchange capacity (C.E.C.), exchangeable cations, available (sodium bicarbonate extractable) phosphorus and organic matter content (MacDonald, 1977).

(ii) Intensive sampling of organic and inorganic horizons involved three separate efforts. In each series, samples were collected using a core sampler to determine the thickness of the total or of individual organic horizons and their weights. The data on the thickness and weight of the organic horizons were used to express the nutrient levels on a volume basis.

Series I: Five groups of six samples (30 replicates) were obtained in each plot from an area where no disturbance had been caused during the plot selection and establishment. The total thickness of the L+F+H hor-

Table 1. Location of different stands and dimensions of plots

Stand	Location	Plot size Radius m	Area m²	Area Acre
Red spruce	Rd. 18 near Mill Brook	11.28	405	0.10
White spruce	Rd. 4 and 16	7.98	202	0.05
Red pine	Rd. 1, East of Rd. 3	15.84	810	0.20
White pine	Rd. 1, South of Rd. 13	15.84	810	0.20
Balsam fir	West of H.Q.	11.28	405	0.10
Larch	Rd. 4, South of 16	11.28	405	0.10
Maple	Rd. 10 and 16	15.84	810	0.20
Birch	Rd. 4, North of 16	11.28	405	0.10
Aspen	Rd. 1 and 13	11.28	405	0.10

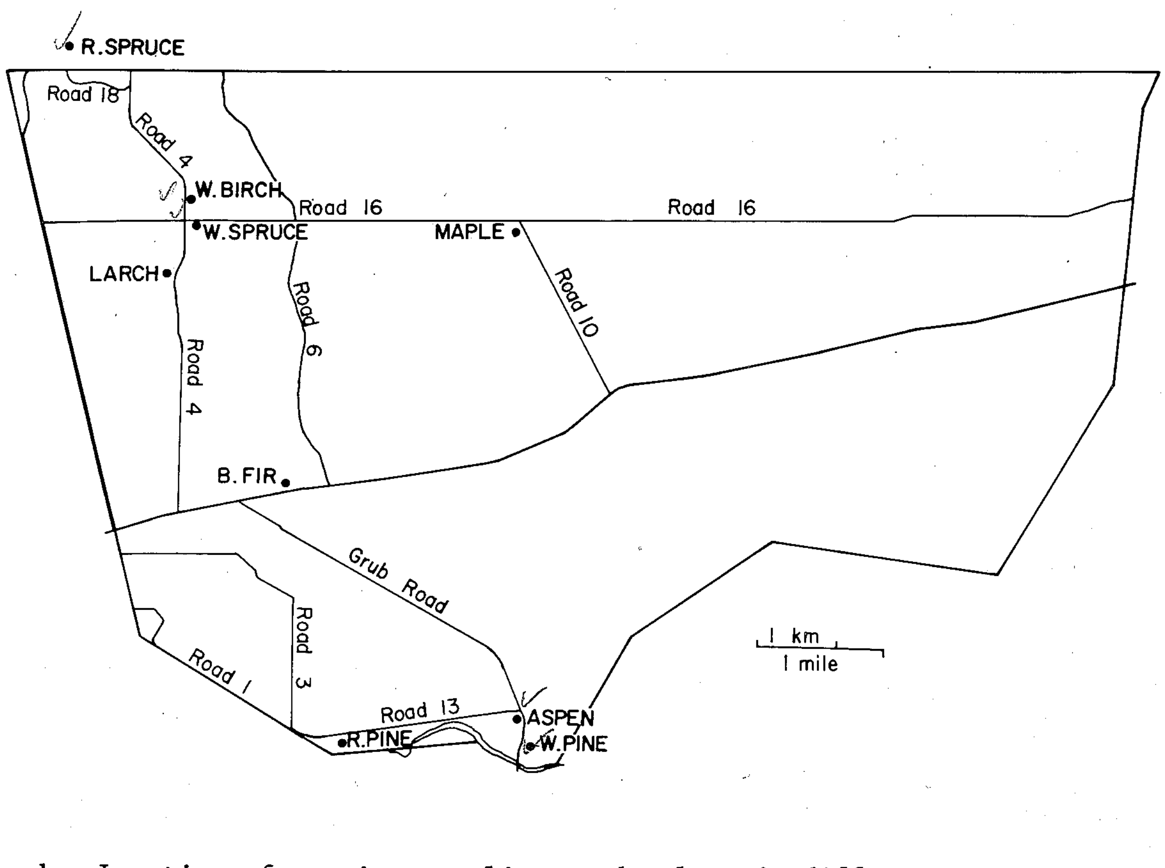

Fig. 1. Location of nutrient cycling study plots in different stands at the Acadia Forest Experiment Station.

Table 2. Numbers and types of collection systems set up in the different plots of each stand

Plot No.	Treatment	Litter screens m^2	S.F. collars	T.F. collectors 29.2	78.5	10,000**
1	Control	2	0*	5	1	1
2	Control	2	5	5	1	1
3	+225 kg N/ha	2	5	5	1	1
4	+225 kg N/ha	2	5	5	1	1

Note: S.F., stemflow; T.F., throughfall.
* Until 1976 Plot 1 also had 5 trees with stemflow collars.
** Area of T.F. collectors (cm^2).

izons was recorded and the samples were oven-dried (60°C) for weight determination.

Series II: To avoid any further disturbance of the plots, samples were obtained from outside the plots. Again the core sampler was used, but this time the L, F, and H horizons were collected separately. The thickness of each horizon was measured in the field using a plastic ruler. The core sampler causes some compaction of the horizons and does not seem ideally suited to accurately measure the thickness of the separate horizons. Hence, the measured values for the thickness of the organic horizons should be considered only as estimates of the true values.

The above two samplings were carried out during late spring 1976 and at that time, the soil under the larch (Larix sp.) stand was very wet, so no samples were collected from that area.

Series III: During mid to late August 1976, one growing season after the fertilizer treatment (two plots in each stand), samples of organic and mineral horizons were collected. This sampling was carried out a) to obtain additional data on the thickness of each horizon in the control plots, and b) to determine the extent of the movement of the added fertilizer nitrogen (data not reported here). At this time, all samples were collected from within the inner circle of each plot where the other parameters were to be measured. From each plot, 15 samples were collected with the core sampler and the thickness of each organic (L, F, and H) horizon was measured in the field prior to oven drying and weighing. Under the larch stand, the organic horizons were collected, in increments of 5 cm, starting at the surface down to the mineral layer. This was necessary because sphagnum moss grew throughout the stand and differentiation of the separate horizons was impossible.

In summary, the average thickness and weight of each horizon, except in the larch stand, were determined using up to 120 core-samples and the average values for the nutrient concentrations were obtained from the analyses of at least 30 samples.

Processing and analyses of samples

Both organic and mineral soils were oven-dried at 60°C. The dried mineral soils were ground using a mortar and pestle and a portion was screened through a 2-mm sieve and used for all analyses except nitrogen. The organic horizon samples were ground in a Wiley Mill fitted with a 2-mm sieve. The samples, thus prepared, were analyzed using methods described by MacDonald (1977). Total N in all samples was determined using a semimicro Kjeldahl method (Mahendrappa 1978). The mineral soil samples were further screened through a 1-mm sieve for total N determinations. These samples were digested for about 6 h after clearing as compared to 3 h of digestion required for the organic horizons.

RESULTS

Most of the results reported here are related to other data on nutrient cycling and will form a base line reference for the results of the on-going nutrient cycling studies. The results are, therefore, presented without much discussion. The type of data presented in this report is not available for the soils of this region and similar information is limited for other regions of Canada. These data can be used as base line characteristics for evaluating the effects of LRTAP and for ecological land classification.

Chemical and physical characteristics of the mineral soils, determined in the field during profile description and through laboratory analyses of the mineral soils collected from the soil pits, are presented in Table 3. These values represent an average of at least four determinations.

The soils under study at the Acadia Forest Experiment Station are Orthic Humo-Ferric podzol derived from glacial till. The differences that are found in the physicochemical characteristics of these soils can partly be attributed to the kind of forest stands growing on them and partly to the drainage characteristics of the local area. Gleying was evident in the soil under only the aspen (Populus sp.) and larch stands and is the result of impeded drainage on these sites.

Data on the various physical and chemical characteristics of the organic horizons are presented in the tables and figures. In the tables, the complete data (all stands and all nutrients determined) are included while in the graphs only the data for depth, weight, and nitrogen contents of the organic horizons of two hardwood (Acer sp. and Betula sp.) and two softwood (Picea rubens Sargent and Pinus resinosa Ait.) stands are presented.

The thickness and weights of the organic horizons are presented in Table 4. Comparison of the data on the organic horizons in Figs. 2 and 4 suggests that the thickness of the L horizons under the softwoods is greater than that under the hardwoods. The total thickness of L+F+H horizons under the white pine stand, however, is considerably less than that under either the hardwoods or the red spruce stand. The oven-dry weight (Fig. 3) of the organic horizons of all the stands increased in the order of H > F > L. Contrary to the thickness, the weight of the individual organic horizons under the softwoods was higher than that under the hardwoods. This was particularly true under the red pine stand with a thin organic horizon but with the highest mass. This is reflected in the high values for the weight of organic material expressed on a unit volume basis (Table 4).

Although the core sampler does not appear to be ideally suited for determination of the thicknesses of the organic horizons, the coefficient of variation for the data on both thickness and weight was as low as 15

Table 3. Chemical and physical characteristics of the mineral horizons under different forest stands

Species	Horizon / Depth (cm)	Color	Proportion of Sand (%)	Silt (%)	Clay (%)	Texture Class	CEC me/100g	Exchangeable cations me/100g Ca	Mg	Na	K	Available P (%)	Organic matter (%)
Red spruce	Ae 0-5	10YR 6/2	65.4	21.3	9.3	sl	3.40	<0.14	0.04	0.14	0.03	0.050	1.8
	B1 5-15	5YR 5/8	74.4	19.3	7.3	ls	8.80	0.14	0.07	0.20	0.06	0.050	13.2
	B2 15-47	7-5YR 5/8	67.4	23.3	9.3	sl	3.50	<0.12	0.04	0.14	0.04	0.050	6.3
	B C 47-	10YR 5/6	72.4	18.3	9.3	ls	3.00	0.10	0.04	0.16	0.04	0.050	3.2
White spruce	Ap 0-7	10YR 4/1	55.4	27.3	17.3	sl	10.0	0.20	0.06	0.20	0.11	0.020	6.7
	B 7-50	10YR 5/4	56.4	24.3	19.3	sl	7.13	<0.11	0.04	0.21	0.07	0.010	4.1
	B C 50-	10YR 4/3	44.4	26.3	29.3	scl	5.74	<0.16	0.05	0.17	0.08	0.020	4.1
Red pine	Ae 0-7	10YR 5/2	51.4	31.3	17.3	l	10.43	0.77	0.12	0.16	0.07	0.004	5.3
	B1 7-39	5YR 5/8	63.4	21.3	15.3	sl	8.94	0.30	0.04	0.18	0.08	0.005	12.0
	B2 39-66	7-5YR 4/4	57.4	29.3	13.3	sl	2.93	0.19	0.05	0.18	0.05	0.002	2.8
	B C 66-	5YR 4/3	32.4	42.0	25.6	l	6.62	0.62	0.21	0.18	0.09	0.001	3.0
White pine	Ae 0-7.0	10YR 5/2	-	-	-	-	-	-	-	-	-	-	-
	B1 7-42	5YR 5/4	53.8	28.3	17.9	sl-l	4.72	0.26	<0.05	0.17	0.05	0.005	4.0
	B2 42-73	7-5YR 4/4	57.9	25.5	16.6	sl	2.89	0.15	<0.005	0.15	0.04	0.002	3.1
	B C 73-	5YR 4/2	60.9	22.5	16.6	sl	7.81	0.61	0.13	0.17	0.05	0.001	2.8

Table 3. Contd.

Species	Horizon / Depth (cm)	Color	Proportion of Sand (%)	Silt (%)	Clay (%)	Tex. Class	CEC me/100g	Exchangeable cations me/100g Ca	Mg	Na	K	Available P (%)	Organic matter (%)
Balsam fir	Ae 0-7	7-5YR 6/2	53.9	31.5	14.6	sl	7.09	0.37	0.06	0.16	0.04	0.001	2.4
	B1 7-35	5YR 4/4	52.2	33.2	14.6	sl-l	11.40	0.26	0.07	0.18	0.10	0.001	8.9
	B2 35-8	7-5YR 4/4	55.2	27.2	17.6	sl	4.69	0.18	<0.05	0.17	0.06	0.001	3.4
	B C 58-	10YR 4/4	44.2	28.6	26.2	scl-l	4.31	0.75	0.26	0.18	0.10	0.002	2.8
Maple	Ae 0-7	5YR 6/2	57.8	33.9	8.3	sl	13.01	1.15	0.54	0.17	0.11	0.006	7.9
	B1 7-32	5YR 5/8	57.4	29.3	13.3	sl	8.79	0.23	0.06	0.17	0.04	0.001	8.3
	B2 32-60	5YR 4/8	53.1	27.9	19.0	sl	6.44	0.20	<0.05	0.17	0.05	0.001	5.0
	B C 60-	7YR 5/6	59.4	20.6	20.00	sl-scl	3.36	0.21	<0.04	0.17	0.04	0.001	2.9
White birch	Ah 14.0	10YR 3/1	-	-	-	-	21.83	0.39	0.30	0.27	0.28	0.004	18.1
	B1 4-16	10YR 4/4	61.9	25.8	12.3	scl	10.60	0.15	0.09	0.19	0.12	0.001	8.6
	B2 16-50	10YR 5/8	59.4	23.3	17.3	scl	5.33	0.12	<0.04	0.15	0.04	0.001	3.9
	B C 50-	10YR 4/4	53.8	22.9	23.3	scl	5.28	0.12	<0.04	0.19	0.05	0.001	3.8
Aspen	Aeg 0-15	7-5YR 7/2	51.6	27.1	21.3	scl	8.33	0.36	0.10	0.18	0.06	0.001	2.6
	Bg 15-50	5YR 5/2	43.0	23.7	33.3	l	6.83	0.44	0.11	0.18	0.09	0.002	4.0
	B Cg 50-	2-5YR 4/2	39.6	25.1	35.3	l-cl	8.16	1.89	0.56	0.20	0.14	0.003	3.5

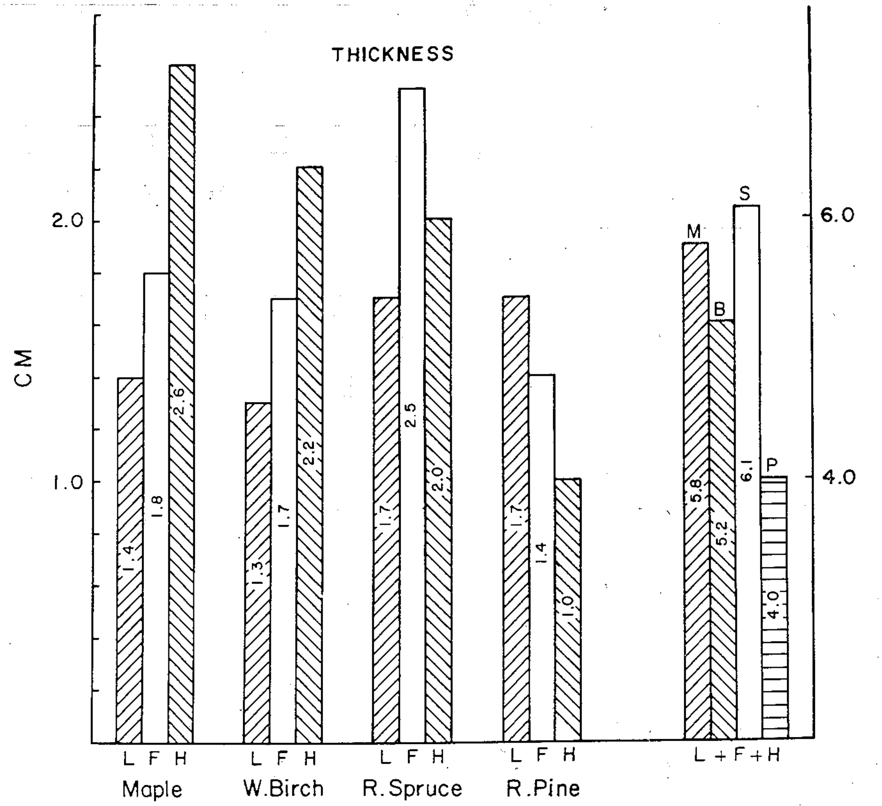

Fig. 2. Average thickness of L, F, and H horizons under two hardwood and two softwood stands.

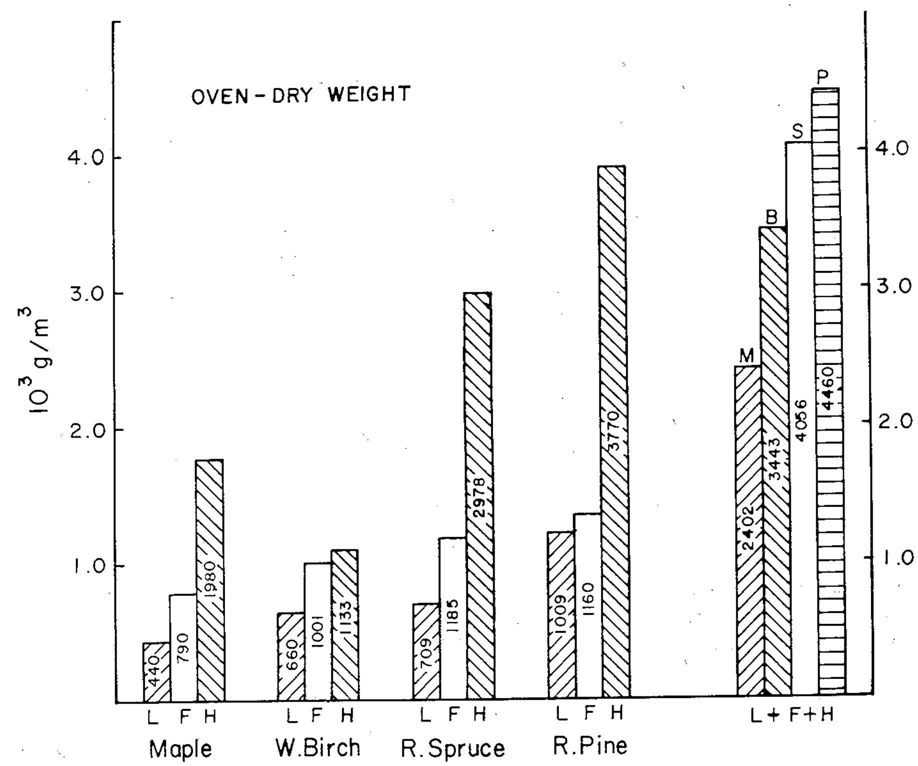

Fig. 3. Oven-dry weights of L, F, and H horizons under two hardwood and two softwood stands.

Table 4. Average thickness, oven-dry weight and percent ash contents of organic horizons under different stands (averages of at least 60 determinations)

Species	Thickness	Ash	Oven-dry weight			
	(cm)	%	kg/ha	C.I.*	g/m^3	C.I.*
			L Horizon			
Red spruce	1.70	4.79	15038	1090	885	64.1
White spruce	1.17	6.24	8990	1919	770	164.5
Red pine	1.68	7.37	13146	2880	784	171.8
White pine	1.55	7.72	11346	1154	733	74.6
Balsam fir	1.55	4.79	13545	1282	874	82.7
Larch	5.00	4.02	29139	4277	583	85.5
Maple	1.44	7.76	6328	1054	440	73.4
Birch	1.28	7.17	8475	1735	661	134.5
Aspen	1.04	13.02	12916	3381	1175	325.7
			F Horizon			
Red spruce	2.48	5.05	27429	2725	1105	109.8
White spruce	1.96	8.53	16324	4423	834	225.9
Red pine	1.36	12.73	16052	4147	1176	303.8
White pine	0.87	24.70	14931	10562	1726	1221.0
Balsam fir	1.85	6.27	20919	2422	1133	131.3
Larch	4.26	8.63	63819	10871	1497	254.9
Maple	1.77	11.61	14016	4728	790	266.5
Birch	1.69	12.86	16868	4828	1001	286.5
Aspen	2.34	16.03	53890	24586	2301	1049.2
			F Horizon			
Red spruce	1.94	25.73	40041	6029	2066	311.1
White spruce	3.71	21.35	78064	32034	2105	863.9
Red pine	0.97	40.79	24229	19199	2500	1981.3
White pine	0.38	58.46	15919	8964	4140	2334.4
Balsam fir	1.66	23.46	36234	3607	2178	160.8
Larch	0.69	27.28	23524	11288	3429	1645.4
Maple	2.61	26.10	30639	12545	1781	664.9
Birch	2.24	27.90	39928	14907	1134	160.8
Aspen	1.62	31.23	72876	48896	1172	479.7
			L + F + H Horizons			
Red spruce	6.12	15.04	82509		4056	
White spruce	6.83	18.01	103379		3709	
Red pine	4.01	24.14	53428		4460	
White pine	2.80	32.87	42198		6605	
Balsam fir	5.05	14.80	70698		4185	
Larch	9.95	11.24	116482		5509	
Maple	5.83	19.84	50983		2402	
Birch	5.21	21.32	65271		3443	
Aspen	5.00	23.74	138961		7972	

* Confidence intervals.

to 20%. This variation is similar to the data obtained earlier (Mahendrappa 1978) by collecting 900-cm^2 samples of forest floor materials with a shovel, and is much smaller than those observed by Gessel and Balci (1963) and Wooldridge (1968). Mader et al. (1977) also observed large variations in the thickness of L, F, and H horizons under different stands in the New England States.

Considering the heterogeneity of forest floor materials, however, few generalized conclusions can be drawn concerning the effects of hardwood and softwood stands on the thickness or weights of organic horizons under these stands. Except for the larch stand, in which moss growth contributed most to the organic horizon, the spruce stands have the thickest organic horizons, followed by the hardwoods and then by the pines. White pine has the thinnest organic horizon. With the exception of the aspen stand, the weights of the organic horizons under these stands followed the same pattern as that of their thickness. These results compare with those of Page (1974) who separated the organic horizons into L+F and H layers and found quantitative differences between the thickness of organic horizons under spruce, fir, and hardwoods. Troth et al. (1976) found that the litter layers had greater mass under black spruce than under aspen/birch stands.

The average concentrations of N, P, K, Ca, and Mg in the organic horizons are presented in Table 5. The middle (F) horizon appears to contain a slightly higher level of nutrients than the L or H horizons, except in the larch stand where there was an extensive growth of moss. The organic horizons under the hardwood stands contained higher levels of N than those under the spruce and pine stands (Fig. 4). The total quantities (kg/ha) of different nutrients in the organic horizons, calculated from the data in Tables 4 and 5, are presented in Table 6. In Fig. 4, the quantities of nitrogen in the organic horizons under some of the stands are compared. No distinct difference seems to exist between the quantities of N in the L and F horizons under softwoods and hardwoods. The total amount of nitrogen in the three (L+F+H) horizons is, however, higher for the hardwoods than for softwoods. In general, the nitrogen reserve in the organic horizons is several times higher than the annual nitrogen requirements of most forest trees. In Table 7, the quantities of nutrients in the organic horizons are expressed on a unit volume basis. Although some differences between the size of the total nitrogen reserves under hardwoods and softwoods are recognizable, no such trend is evident when the nitrogen level is expressed on a volume basis (Fig. 5). The organic material under the red pine stand, which has the smallest total quantity of N reserve (Fig. 4) has a similar concentration of nitrogen as that under the hardwoods.

Nitrogen levels in the foliage, litterfall, and organic horizons are compared in Fig. 6. In general, the litterfall contained lower levels of N than either the foliage or the organic horizons. The trees appear to conserve nitrogen through retranslocation of nitrogen from senescing foliage into the active portion of the trees. Spruces and pines appear to be more efficient at this than hardwoods. On the other hand, the nitrogen in the litterfall from hardwoods apparently undergoes rapid turnover and the N levels in the organic horizons under the maple and birch stands exceed those of the foliage. The softwood litter, however, appears to undergo only a moderate change in the nitrogen level in the organic material.

At the time of describing the soil profiles, mineral soil samples were collected for laboratory analysis.

Table 5. Concentrations of some nutrients in the organic horions under different stands (averages of at least 5 determinations)

Species	Concentration (%) of				
	N	P	K	Ca	Mg
			L Horizon		
Red spruce	0.98	0.09	0.10	0.42	0.03
White spruce	1.44	0.12	0.11	0.73	0.05
Red pine	0.72	0.06	0.07	0.57	0.04
White pine	0.94	0.09	0.13	0.63	0.06
Balsam fir	1.53	0.14	0.15	0.80	0.05
Larch	0.85	0.10	0.37	0.08	0.04
Maple	1.57	0.13	0.12	0.91	0.07
Birch	1.41	0.12	0.12	0.82	0.06
Aspen	1.45	0.13	0.14	0.60	0.07
			F Horizon		
Red spruce	1.12	0.09	0.08	0.23	0.03
White spruce	1.65	0.12	0.11	0.41	0.04
Red pine	1.09	0.10	0.09	0.40	0.04
White pine	1.00	0.08	0.07	0.44	0.05
Balsam fir	1.77	0.13	0.11	0.44	0.04
Larch	1.30	0.12	0.09	0.06	0.03
Maple	1.99	0.14	0.10	0.47	0.05
Birch	1.63	0.14	0.15	0.38	0.06
Aspen	1.87	0.13	0.12	0.37	0.06
			H Horizon		
Red spruce	0.71	0.05	0.04	0.13	0.03
White spruce	1.35	0.10	0.06	0.17	0.04
Red pine	0.86	0.06	0.06	0.27	0.04
White p ne	0.63	0.05	0.06	0.22	0.05
Balsam fir	1.24	0.09	0.06	0.26	0.04
Larch	1.69	0.14	0.09	0.04	0.03
Maple	1.71	0.14	0.08	0.19	0.05
Birch	1.19	0.09	0.09	0.21	0.04
Aspen	1.83	0.16	0.12	0.17	0.06

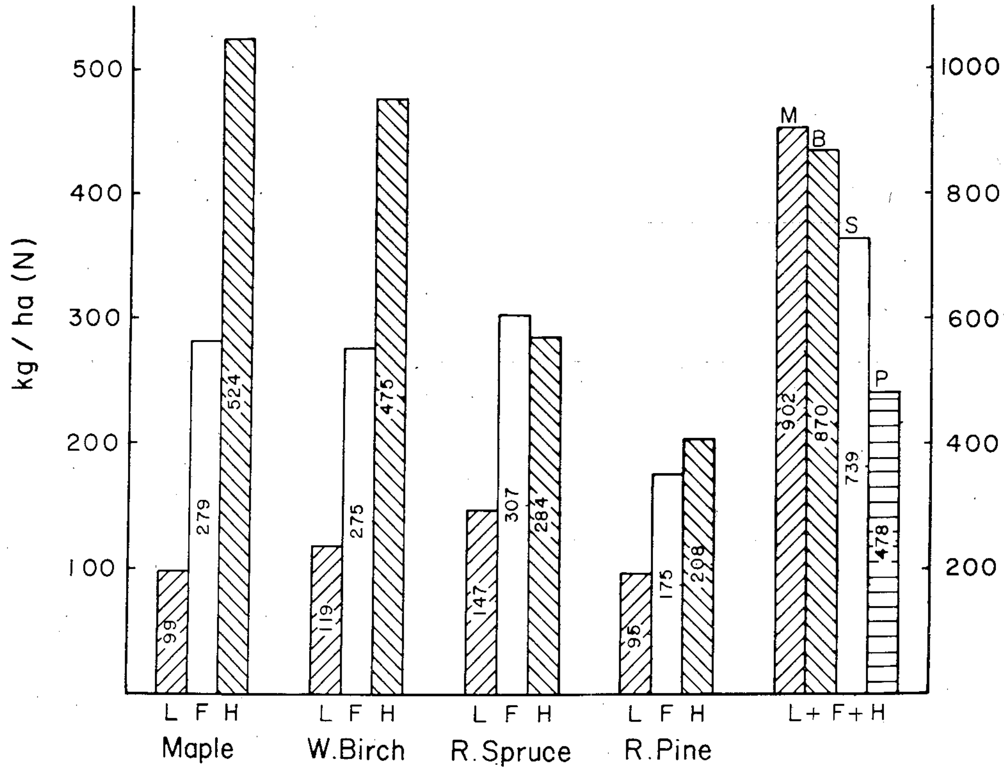

Fig. 4. Quantities (kg/ha) of nitrogen in L, F, and H horizons under two hardwood and two softwood stands.

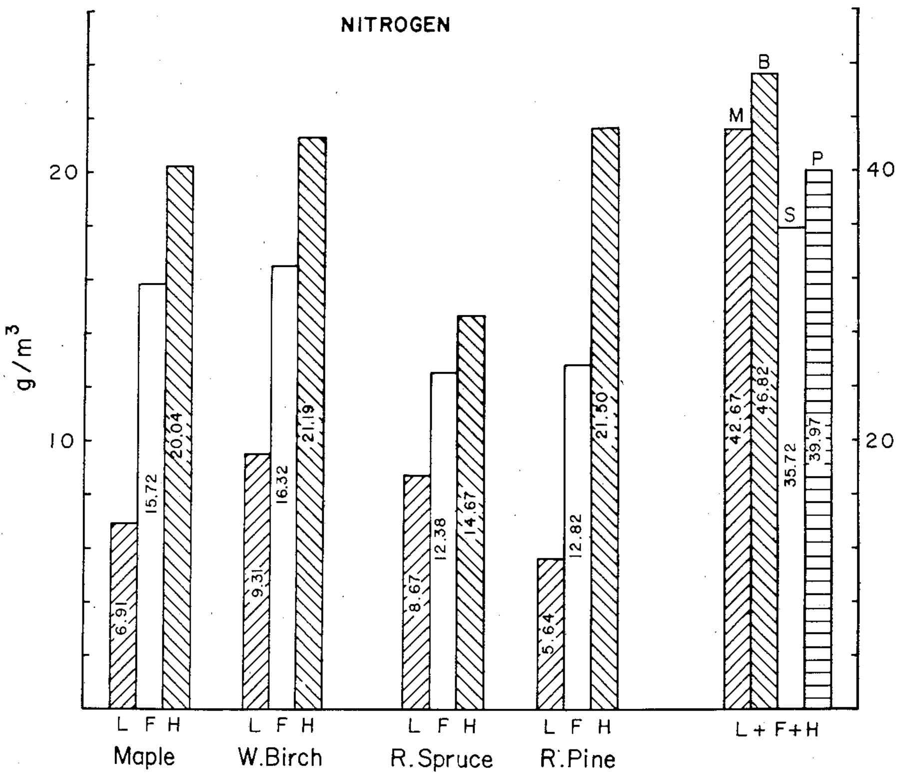

Fig. 5. Grams of nitrogen per cubic metre of L, F, and H horizons under two hardwood and two softwood stands.

Table 6. Average quantities of some nutrients in the organic horizons under different stands, expressed on weight-basis

Species	Nutrients (kg/ha)							
	N	P	K	Ca	Mg	Na	Fe	Mn
				L Horizon				
Red spruce	147	14	15	63	5	1	6	3
White spruce	129	11	10	66	5	1	5	3
Red pine	95	8	9	75	5	1	4	4
White pine	107	10	15	71	7	1	4	2
Balsam fir	207	19	20	108	7	1	5	4
Larch	248	28	108	23	12	10	49	1
Maple	99	8	8	58	4	1	2	3
Birch	119	10	10	69	5	1	4	2
Aspen	177	16	17	73	9	2	20	2
				F Horizon				
Red spruce	307	24	22	63	8	2	18	3
White spruce	269	19	18	67	7	1	15	4
Red pine	175	15	14	64	6	2	13	7
White pine	149	12	10	66	7	2	12	7
Balsam fir	370	28	23	92	8	3	18	5
Larch	830	76	57	38	19	10	266	2
Maple	279	20	14	66	8	1	9	7
Birch	275	23	25	64	8	2	15	4
Aspen	1008	72	65	199	32	8	158	11
				H Horizon				
Red spruce	288	20	16	52	12	3	45	3
White spruce	1054	75	47	133	31	8	163	10
Red pine	208	15	15	65	10	2	53	13
White pine	100	8	10	35	8	2	25	8
Balsam fir	449	34	22	94	14	4	77	5
Larch	398	33	21	9	7	4	87	1
Maple	524	42	25	58	15	3	34	18
Birch	475	37	36	84	16	4	64	6
Aspen	1334	120	87	124	44	12	273	9
				L + F + H Horizons				
Red spruce	739	58	53	178	25	6	69	8
White spruce	1453	105	75	265	42	10	183	18
Red pine	478	38	38	205	21	5	70	24
White pine	356	30	35	172	22	5	41	17
Balsam fir	1025	80	65	295	20	8	100	15
Larch	1475	137	186	71	38	24	402	3
Maple	902	70	46	182	28	5	44	28
Birch	870	70	71	217	29	6	83	12
Aspen	2518	207	169	396	85	22	451	23

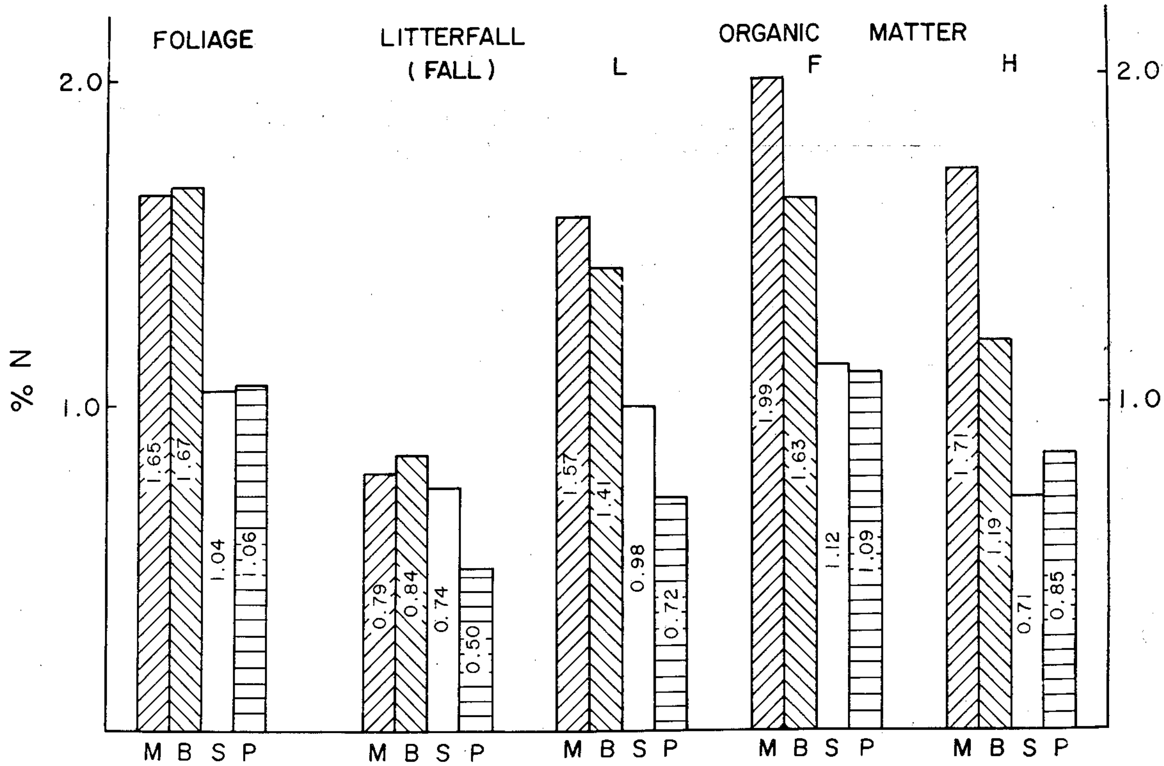

Fig. 6. Concentrations (percent) of nitrogen in the foliage, litterfall materials, and the organic (L, F, and H) horizons under two hardwood (M = Maple, B = Birch) and two softwood (S = R. spruce and P = R. pine) stands.

During the three intensive sampling efforts in 1976, mineral soil samples to a depth of 30 cm were collected for analysis. Average values from both analyses of the samples (i.e., samples collected from soil pits and those obtained with core sampler) were used for calculating the size of the nutrient pools in the upper 30 cm of the mineral soil (Table 8). Large variations were found in the quantities of nutrients under these stands and consequently no significant differences can be identified between the quantities of nutrients under the hardwoods and softwoods. Consistently larger quantities of nitrogen are found in the mineral than in the organic horizon (Table 9). In the larch and aspen stands, the proportion of organic N as compared to the size of the total nitrogen pool in the soil is much larger than that in the other stands. This is a reflection of slow decomposition of the litterfall materials in these stands and is probably the result of extended periods of water saturation and poor drainage under these stands. In the other stands, the nitrogen in the organic horizon constitutes about 10-17% of the total N in the soil. These values agree well with those reported by Cole et al. (1967).

Table 7. Average quantities of some nutrients in the organic horizons under different stands, expressed on volume basis

Species	Nutrients (g/m^3)							
	N	P	K	Ca	Mg	Na	Fe	Mn
				L Horizon				
Red spruce	8.26	0.78	0.84	3.54	0.25	0.06	0.35	0.14
White spruce	10.40	0.85	0.79	5.27	0.36	0.05	0.38	0.25
Red pine	5.23	0.44	0.51	4.14	0.29	0.06	0.23	0.21
White pine	6.36	0.60	0.88	4.25	0.41	0.06	0.22	0.13
Balsam fir	12.73	1.15	1.25	6.66	0.42	0.09	0.29	0.25
Larch	4.75	0.54	2.07	0.45	0.22	0.19	0.94	0.02
Maple	6.38	0.51	0.49	3.70	0.28	0.04	0.10	0.17
Birch	8.65	0.74	0.74	5.03	0.37	0.05	0.26	0.15
Aspen	14.82	1.32	1.43	6.13	0.72	0.13	1.67	0.16
				F Horizon				
Red spruce	11.75	0.91	0.84	2.41	0.31	0.08	0.70	0.12
White spruce	12.58	0.90	0.84	3.13	0.31	0.06	0.71	0.21
Red pine	11.19	0.98	0.92	4.11	0.41	0.11	0.82	0.43
White pine	13.00	1.01	0.91	5.72	0.65	0.15	1.06	0.60
Balsam fir	18.81	1.40	1.17	4.68	0.43	0.13	0.93	0.28
Larch	17.78	1.63	1.23	0.82	0.41	0.22	5.70	0.03
Maple	13.90	1.00	0.70	3.28	0.42	0.07	0.43	0.37
Birch	14.22	1.21	1.31	3.31	0.44	0.09	0.77	0.21
Aspen	36.13	2.59	2.32	7.15	1.16	0.30	5.65	0.41
				H Horizon				
Red spruce	10.89	0.78	0.61	1.99	0.46	0.10	1.72	0.11
White spruce	22.35	1.59	0.99	2.81	0.66	0.16	3.46	0.22
Red pine	12.73	0.89	0.89	4.00	0.59	0.12	3.25	0.81
White pine	10.85	0.91	1.03	3.79	0.86	0.20	2.75	0.85
Balsam fir	20.67	1.55	1.00	4.33	0.67	0.16	3.54	0.23
Larch	42.14	3.49	2.24	1.00	0.75	0.39	9.21	0.07
Maple	14.81	1.19	0.69	1.65	0.43	0.08	0.95	0.51
Birch	15.28	1.18	1.16	2.70	0.51	0.12	2.07	0.18
Aspen	56.58	5.07	3.71	5.26	1.86	0.50	11.56	0.40
				L + F + H Horizons				
Red spruce	30.91	2.48	2.30	7.95	1.03	0.24	2.77	0.37
White spruce	45.34	3.33	2.63	11.21	1.33	0.27	4.55	0.67
Red pine	29.15	2.31	2.32	12.24	1.29	0.29	4.29	1.45
White pine	30.21	2.52	2.82	13.77	1.92	0.41	4.03	1.58
Balsam fir	52.21	4.10	3.42	15.67	1.51	0.38	4.76	0.76
Larch	64.68	5.66	5.54	2.27	1.38	0.80	15.85	0.12
Maple	35.08	2.71	1.88	8.62	1.14	0.19	1.48	1.04
Birch	38.14	3.13	3.20	11.04	1.32	0.26	3.10	0.54
Aspen	107.53	8.98	7.46	18.54	3.73	0.93	18.88	0.97

Table 8. Quantities (kg/ha) of different nutrients in the upper 30 cm* of mineral horizon

Species	Total N	Available P	Exchangeable K	Exchangeable Ca	Exchangeable Mg
Red spruce	3566	86	1504	39.6	792
White spruce	14660	49	2377	79.2	1189
Red pine	3170	141	2774	118.9	2020
White pine	4041	190	3170	118.9	2020
Balsam fir	5866	56	3566	39.6	2377
Larch	2020	219	3962	39.6	2020
Maple	7370	76	2020	79.2	1504
Birch	7290	90	3170	79.2	2020
Aspen	2377	143	4754	118.9	2377

* Ae horizon materials were not sampled for analysis.

Table 9. Size of total nitrogen pool in the organic and upper 30 cm mineral horizons

Species	kg N/ha Organic (L + F + H)	kg N/ha Mineral	kg N/ha Total	Organic N as percent of total
Red spruce	739	3566	4305	17.16
White spruce	1453	14660	15113	9.61
Red pine	478	3170	3548	13.47
White pine	356	4041	4397	8.09
Balsam fir	1025	5866	6891	14.87
Larch	1475	2020	3495	42.20
Maple	902	7370	8272	10.90
Birch	870	7290	8160	10.66
Aspen	2518	2377	4895	51.44

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