VARIABILITY IN FOREST FLOOR COMPONENTS IN SOUTHWESTERN ILLINOIS UPLAND FORESTS

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ABSTRACT

The forest floor is a dynamic and complex system and the resulting variability within components may be large, making it difficult to assess smapling intensities. This variability must be known to estimate sampling intensities required for a given level of precision. Within plot variability in the distribution of organic matter and several macro- and micro-nutrient concentrations were estimated on two watersheds in the unglaciated part of southwestern Illinois. Predominant vegetation types consisted of oak-hickory forests on upper slopes and ridges and mixed hardwood forests on lower slopes and ravine bottoms. Within plot variability of organic matter was determined separately for O_1 and O_2 horizons from samples harvested from four 0.25 m^2 quadrats randomly located within twelve 0.04 ha circular plots (six 0.04 ha plots per watershed). Plots in which the O_1 horizon weights had the largest and the smallest coefficients of variation (C.V.) were identified and eight additional 0.25 m^2 samples were taken from each. Variability was large and often difficult to estimate with certainty. Some attributes were not normally distributed which affected estimates of required sample size. Samples required for estimates of ± 10% of the mean at 95, 90, and 80% levels of precision ranged from 1-900+ per 0.04 ha plot, depending on the particular attribute. The formula used to estimate sample size gave spurious results in some cases.

INTRODUCTION

The forest floor which is comprised of dead organic detritus and woody material has been shown to contain a large portion of the mineral nutrient capital in the forest ecosystem and is important in mineral nutrient cycling. Also, the forest floor may contain a large portion of above-ground biomass and is a key factor in forest productivity (Rodin and Basilevich, 1967; Westman, 1975; and Youngberg, 1966). The major problem encountered when studying the forest floor is the large variability in the distribution of the material. This makes it difficult to estimate forest floor parameters with precision (Bourn and Brown, 1971; Grier and McColl, 1971; McFee and Stone, 1965; and Woolridge, 1968). The universal question is how many and what size of samples must be taken for adequate descriptions of forest floor compartments.

In a study of variability within a small plot (0.04 ha), Grier and McColl (1971) found that by increasing the area of each sample from 140 cm^2 to 560 cm^2, the numbers of samples required for estimating O_1 and O_2 horizon weights could be reduced from 39 to 26 samples. Their study was conducted in a 40 year-old even-aged plantation, and large woody material was excluded from samples. They concluded that all measured properties (weight and nutrient concentrations) could be estimated with fewer than 30 samples (each 560 cm^2), except Mg which required 57 samples and oven-dry weight which required 39 samples (each 140 cm^2).

McFee and Stone (1965) sampled the forest floor under yellow birch-red spruce forests on seven 0.10 acre (0.04 ha) plots. Within each plot, 96 samples (each 59 cm^2) were taken. They found that some reduction in variability could be achieved by taking larger numbers of samples, but a total sample area of about one milacre would be required to consistently cover the extremes in humus thickness caused by tree fall mounds, partially decayed stumps, and logs. They concluded that a minimum sample of 25 observations (59 cm^2) per 0.10 acre plot was required to place reasonable confidence limits on the mean values of forest floor weights. To reduce the standard error to 10% of the mean, 50 observations (59 cm^2) were needed.

Bourn and Brown (1971) sampled the forest floor under mixed oaks using a sample frame of 2.2 sq. ft. (1.21 m^2) and excluding twigs and branches larger than 0.25 inches in diameter (0.63 cm). With 111 samples the mean could be estimated to $\pm$ 500 lb./acre (0.6 mt/ha).

These studies indicate that the spatial distribution of forest floor detritus is highly variable and that sampling intensities required to achieve a given level of sampling error and precision may vary among forest types. The purpose of the present study was to determine within plot variability in the distribution of organic matter and several macro- and micro-nutrient concentrations for upland hardwood forests in which intensive nutrient cycling studies are planned. From these data estimates of the number of $.25m^2$ samples per 0.04 ha plots required for $\pm$ 10% of the mean organic matter and nutrient concentrations for O_1 and O_2 horizons at three levels of precision (95, 90, 80%) were determined.

STUDY AREA

The study was conducted in a forested watershed in the Trail of the Tears State Forest (T.12S., R2W), Union County in southwestern Illinois. This area is approximately 80 ha in size, has not been glaciated and topography is exceedingly dissected with maximum relief of about 60 meters. This region is part of the Salem Plateaus Section of the Ozark Plateaus Province (Leighton *et al.*, 1948). The study area is underlain by Clear Creek chert of Devonian age at least 90 m thick. Clear Creek chert is novaculitic, somewhat calcareous, with alternating chert and limestone layers 7.6 to 20.0 cm thick. (Savage, 1920; Weller and Ekblaw, 1940).

The soils in this area were developed primarily from Peorian loess greater than 6 m (20 ft.) thick. The Peorian loess when depositied was calcareous and well supplied with all plant nutrients except nitrogen (Fehrenbacher *et al.*, 1967). The soil series (7th approximation) which cover the majority of the study area are Goss-Alford complex (Typic Paleudalf, typic Hapludalf and Elash) (Typic Udifluvent) (Miles, SCS Party Chief, personal communication, 1976). The Alford (series) is very limited, occurring only on the larger, flatter ridgetops. Goss-Alford complex occurs on the slopes, ravines and convex ridge tops and leads. Elsah (Typic Udifluvent) occurs along overflow channels where the surface layer is a cherty silt loam. At greater distances from the stream channel, soils of this seris (Elsah) are comprised of silt loam sediments overlying cherty materials.

Trewartha (1968) classifies the climate of this area of Cf, subtropical humid with hot summers and high absolute

and relative humidity. Average annual temperature for 104 years is 14.9° C (58.7° F) and the average precipitation for the same period is 110 cm (43.3 inches), based on data from Cairo, Illinois, about 40 km south of the study area. The average frost free period is over 200 days (NOAA 1975).

The potential natural vegetation of this area has been classified by Küchler (1965) as Broadleaf, Oak-Hickory. Braun (1950) included this region in the Western Mesophytic Forest Region of the Eastern Deciduous Forest Formation.

Sanders (1953) recognized five forest communities in the study area. *Ulmus americana* L., characterize the floodplain. *Fagus grandifolia*, *Acer nigrum* Michx. (probably *Acer saccharum* Marsh.) and *Liriodendron tulipifera* L. dominate on north and lower south slopes. *Quercus velutina* and *Quercus alba* forests occupy upper and middle south slopes. The most common community in the watershed and in which this study was done occupies remaining mid-slopes and ridges and is dominated by *Q. velutina*, *Q. alba*, *Carya glabra* Mill., and *C. ovata* (Mill.) K. Koch, with *F. grandifolia*, *Magnolia acuminata* L., and *L. tulipifera* as associates.

The basal area (B.A.) ranges from 11.7-42.0 m^2/ha (50.3-180.5 $ft.^2$/a) with a mean of 24.2 m^2/ha (104.3 $ft.^2$/a). Generally the forest is will stocked, appears to be uneven-age (Rossen, unpublished data), relatively free from recent anthropogenic disturbance, and in late secondary succession (Sanders, 1953).

METHODS

The study was initiated during the fall of 1974. Six 0.04 ha circular plots were randomly selected from 56 possible plots in which standing crops of forest floor biomass and nutrients were to be estimated. On each plot, four 0.25 m^2 subsamples (O_1 and O_2 horizon) were taken from randomly selected locations. The plots which had the largest and smallest coefficients of variation (standard deviation/mean) for O_1 litter weights were identified, and from these plots eight additional random subsamples were taken.

The following criteria were used to identify and separate the O_1 and O_2 horizons: O_1 consisted of all dead organic material the source of which could still be recognized including parts of branches greater than 0.5 m in length and $\leq$ 2.5 cm diameter. The O_2 horizon consisted of

all dead organic material of which the source could not be recognized. Also included in both horizons were fungal hypae, small micro-organisms, and fine roots which could not be separated. Difficulty was encountered in separating the 0_2 from the mineral A_1 horizon. This was corrected by removal of as much as possible of the mineral soil in the laboratory.

All samples were oven-dried at 70° C to a constant weight and ground in a stainless steel Wiley Mill. Chemical analyses were performed by the University of Georgia Soil and Plant Testing Laboratory. Distributions of all populations (weights and nutrient concentrations) were tested using sample statistics g_1 and g_2 (Sokal and Rohlf, 1969) for two types of departure from normality (skewness and kurtosis).

The estimated number of samples was calculated using the equation (Freese, 1974)

$$n = \frac{t^2 (C.V.^2)}{(AE)^2}$$

where n is the estimated number of samples, t the value for desired level of significance from the t distribution table with D.F. = number of samples taken -1, C.V. the coefficient of variation in percents and AE the acceptable error ± 10% of the mean.

RESULTS

The Importance Values (IV 200) for tree species are given for both study plots in Table 1. Plot 68-50 was dominated by *Q. velutina*, *Q. alba* and *C. ovalis*, with *S. albidum* and *C. florida* in the understory. Plot 66-51 was was primarily dominated by *Q. alba* with a large amount of *C. florida* and *S. albidum* in the understory. Several species were present on plot 66-51 which were not on plot 68-50.

Sokal and Rohlf (1969) g_1 and g_2 tests for departure from normality are given in Table 2. Only plot 66-51 0_1 and 0_2 weights and K concentrations showed significant ($\alpha \leq 0.05$) deviation from the normal distribution, all being skewed right and with leptokurtic shaped curves. Also Fe concentrations in 68-50 exhibited a leptokurtic shaped curve, but was not significantly skewed. Biomass estimates showed a systematic decrease as n - size increased, for each horizon except the 0_2 in plot 68-50. A corresponding trend for C.V. was only apparent for the 0_1 horizon in plot 66-51 (Tables 3 and 4).

TABLE 1. Species Composition and Importance Values for Study Plots[1]

Plot 66-51

Species[2]	IV[3] 200
Acer rubrum L.	4.1
A. saccharum Marsh.	24.8
Cornus florida L.	30.9
Fagus grandifolia Ehrh.	5.8
Fraxinus americana L.	8.2
Magnolia acuminata L.	23.8
Nyssa sylvatica Marsh.	3.9
Quercus alba L.	78.4
Sassafras albidum (Nutt.) Nées	20.1
Total	200.0

Plot 68-50

A. saccharum Marsh.	15.2
Carya ovalis (Wangenh.) Sarg.	38.5
Cornus florida L.	23.6
Q. alba L.	47.5
Q. velutina Lam.	48.8
Sassafras albidium (Nutt.) Nées	26.5
Total	200.0

[1]From Rossen, unpublished data.
[2]trees $\geq$ 6.6 cm dbh
[3]Importance value 200 = % Relative Density + % Relative Basal Area.

TABLE 2. Distribution of forest floor biomass and nutrient concentrations tested for skewness and kurtosis[1]

Variable	Skewness[2] G_1	Kurtosis[2] G_2
	Plot 66-51 0_1	
Biomass	1.937*	4.444*
N	-0.149	-1.466
P	0.052	-1.445
K	3.359	11.430*
Ca	0.248	-1.368
Mg	0.297	-0.980
S	0.122	-1.091
Mn	-0.309	-0.185
Fe	0.465	1.072
Cu	-0.367	-0.875
Zn	0.902	-0.165
	Plot 66-51 0_2	
Biomass	1.669*	2.731*
	Plot 6-85 0_1	
Biomass	0.897	1.386
N	-0.663	-0.478
P	0.089	-1.246
K	0.752	-1.173
Ca	0.380	-1.009
Mg	-0.520	-0.938
S	-0.501	-1.399
Mn	-0.755	0.095
Fe	1.042	3.921*
Cu	0.022	-1.610
Zn	0.485	-0.042
	Plot 68-50 0_2	
Weight	0.219	-0.500

[1]Sokal and Rohlf, 1969

[2]A significance level of 0.05 was employed to test the null hypothesis for no departure from the normal distribution. (*indicates significance).

TABLE 3. Plots 66-51 and 68-50 0_1 litter biomass ($g/\frac{1}{4}m^2$) with estimated number of samples required ± 10% mean at [1]3 levels of precision (95, 90, 80%).

Plot 66-51 0_1

¼m2 Number of Samples Taken	Biomass $\bar{X}$	Standard deviation	C.V.[2] %	Estmimated Number of ($\frac{1}{4}m^2$) Samples Required[2] 95%	90%	80%
2	589.0	264.0	45	3269	807	192
3	457.1	285.1	62	711	328	137
4	428.1	251.9	59	352	193	93
5	446.9	228.5	51	200	118	61
6	420.1	217.1	52	178	110	59
7	389.3	214.6	55	181	114	63
8	380.8	202.0	53	157	101	56
9	362.7	197.2	54	155	101	57
10	346.4	193.4	56	160	105	60
11	354.3	186.1	53	139	92	53
12	354.9	178.2	50	121	81	46

Plot 68-50 0_1

2	427.8	92.8	20	646	159	38
3	452.1	81.15	18	60	28	12
4	428.9	81.0	19	37	20	10
5	426.7	72.6	17	22	13	7
6	397.5	101.9	26	45	27	15
7	403.8	87.4	22	29	18	10
8	397.0	83.7	21	25	16	9
9	390.4	81.1	21	23	15	9
10	384.8	78.8	20	20	13	8
11	373.8	82.7	22	24	16	9
12	366.3	83.1	23	26	17	10

[1]coefficent of variation (C.V.) = $\frac{\text{Standard deviation. } 100\%}{\text{Mean}}$

[2]Number of samples = $\frac{t^2 (\text{C.V. } \%)^2}{(\text{Allowable Error})^2}$. Allowable error = 10% of mean.

TABLE 4. Plots 66-51 and 68-50 0_2 litter biomass. ($g/\frac{1}{4}m^2$) and estimated number of samples required ± 10% mean at 3 levels of percision (95, 90, 80%).

Plot 66-51 0_2

# Samples $\frac{1}{4}m^2$	Biomass $\bar{X}$	Standard deviation	C.V.[2] %	Estimated Number of Samples ($\frac{1}{4}m^2$)[1] 95%	90%	80%
2	41.8	13.3	32	1653	408	97
3	35.3	14.2	40	296	136	57
4	31.8	13.7	43	187	102	50
5	25.5	17.7	69	367	216	112
6	21.2	18.7	88	512	314	169
7	18.2	18.8	104	647	408	224
8	15.1	18.6	117	766	492	274
9	14.1	18.3	129	885	576	325
10	13.6	17.4	128	838	550	313
11	13.0	16.7	129	826	546	313
12	11.9	16.4	138	923	342	354

Plot 68-50 0_2

2	7.5	6.0	80	10,332	2551	606
3	8.4	5.1	60	667	307	128
4	8.1	4.4	55	306	167	81
5	7.1	4.4	63	306	180	93
6	7.0	4.1	58	222	137	73
7	7.5	4.0	53	168	106	58
8	7.6	3.7	49	134	86	48
9	7.4	3.6	48	123	80	45
10	6.7	4.0	61	190	125	71
11	6.4	4.0	62	191	126	72
12	6.3	3.8	61	180	120	69

[1]Number of samples = $\frac{t^2 (C.V.\ \%)^2}{(\text{Allowable Error})^2}$ Allowable Error = ± 10% of mean

[2]coefficient of variation (C.V.) = $\frac{\text{Standard deviation. } 100\%}{\text{Mean}}$

Generally the C.V.% for the plots were ranked (Figure 2) 66-51 0_2 > 68-50 0_2 > 66-51 0_1 > 68-50 0_1. The C.V. for 0_1 fluctuated with fewer than 7 samples but tended to show little change from 8 to 12 samples. The C.V. for 0_2 tended to fluctuate throughout sample size range, and plot 66-51 0_2 was still increasing at sample 12.

The change in C.V. for several macro-nutrients of plots 66-51 and 68-50 0_1 are given in Figure 3. The rank orders magnitude of C.V. were similar: plot 66-51 K > Ca > S > P > N > Mg and plot 68-50 K > Ca + S > N > P > Mg. Again K exhibited the greatest C.V.%, 3 to 5 times greater than the other macro-nutrients.

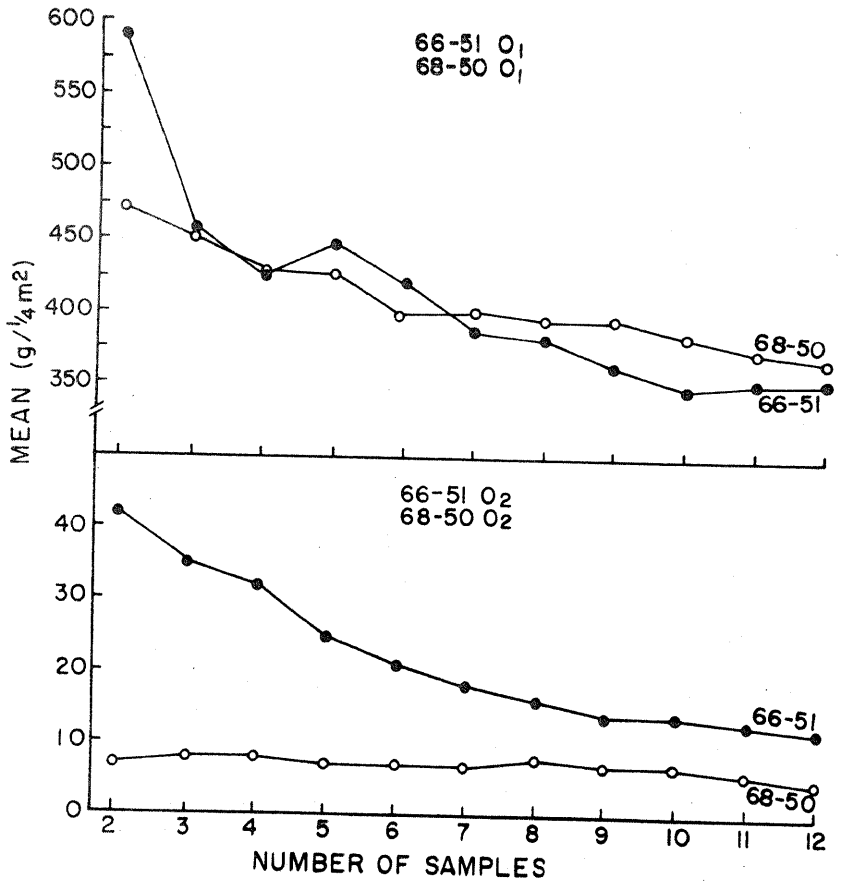
Generally the micro-nutrients (Mn, Zn, Cu and Fe) showed a similar pattern (Figure 4) of wide fluctuation with fewer than 7 samples and exhibiting little change from 7 to 12 samples. The rank orders for both plots were similar except Mn was reversed: plot 66-51 Zn > Cu > Fe > Mn and plot 68-50 Mn > Zn > Cu > Fe.

DISCUSSION

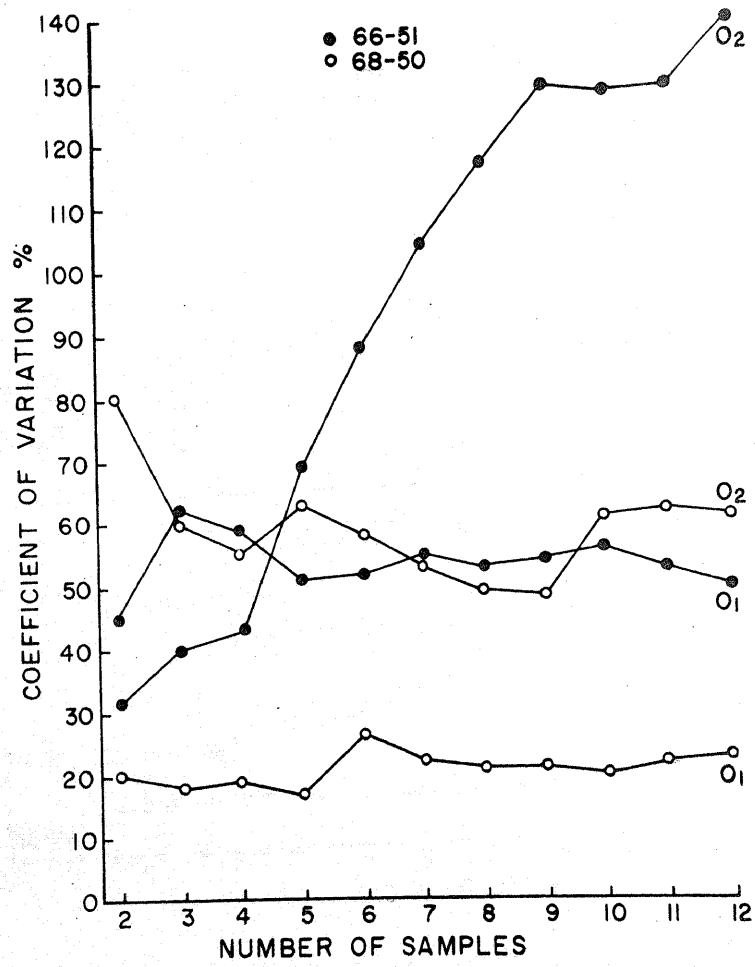
There are no easy ways of determining appropriate sample size but prior knowledge of variability within the data set is always required (Sokal and Rohlf 1969). High variability is an inherent characteristic of the distribution of detritus in many forests. However, the uncertainty of obtaining valid measurements of variance from small numbers of samples is amply illustrated by our results. Graphic assessment of variance suggests that six or more samples may be required to estimate variance for most forest floor attributes studied in these particular hardwood forests.

Awareness of nonnormality in the data is also essential when trying to determine sampling intensity because erroneous estimates of population parameters may be produced. In the present study, nonnormality probably accounts for the systematic change in the estimates of means of litter biomass calculated from increasing sample size and may contribute to the large number of samples which appear to be needed to accurately describe these populations.

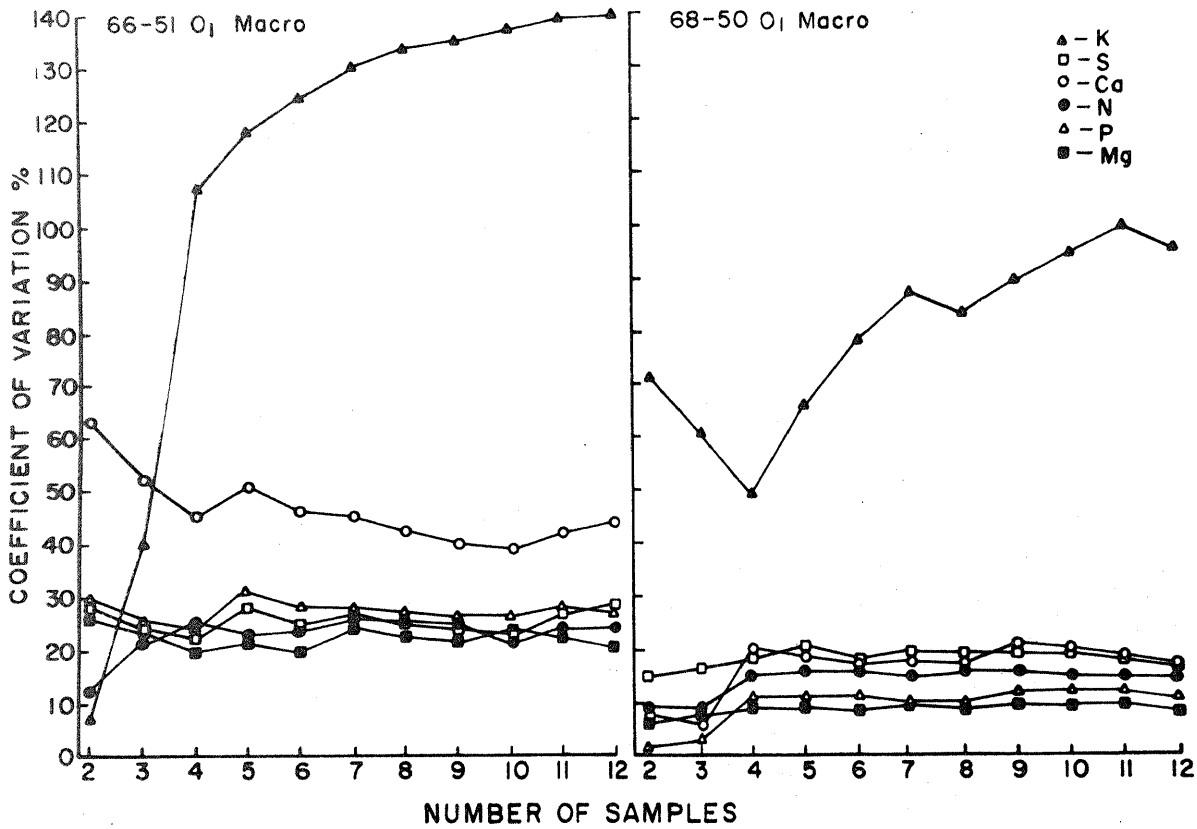
Nonnormality in the distribution of detritus in these plots results from uneven deposition of litterfall (Weaver, unpublished data) and its subsequent redistribution by gravity and wind and water action, especially on complex microtopography. On plot 66-51 were coefficients of variation were largest and departures from normality were



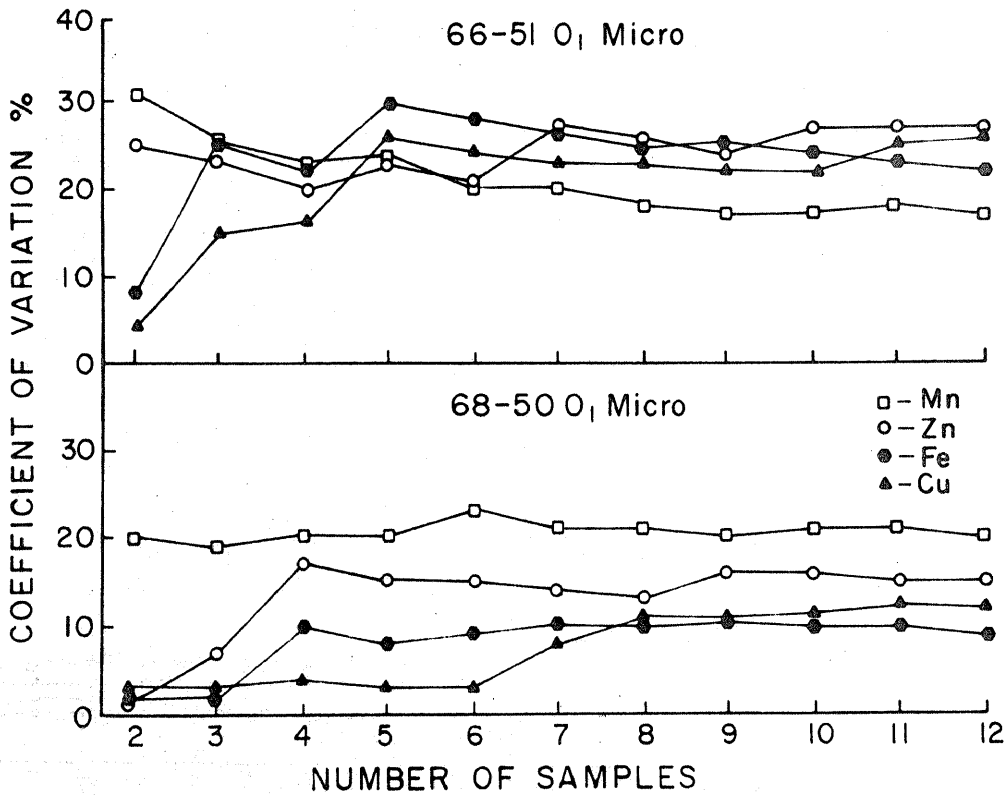
1 The change in O_1 and O_2 mean weights as sample size increases .....



2 The change in the C.V. for O_1 and O_2 weights as sample size increases .....



3 The change in the C.V. for plot 66-51 and plot 68-50 O_1 macro-nutrients as sample size increases .....



4 The change in the C.V. for plot 66-51 and plot 68-50 O_1 micro-nutrients as sample size increases .....

TABLE 5. Number of samples required for estimates of nutrient concentrations in litter (± 10% mean) at three levels of precision.

Nutrient	Nutrient Concentration (ppm)[1] $\bar{X}$	Standard Deviation	C.V.[2] %	Estimated Number of Samples ($\frac{1}{4}m^2$)[3] 95%	90%	80%
		Plot 66-51 0_1				
		Macro-Nutrients				
N	8850	2095	24	28	19	11
P	734	197	27	35	24	14
K	139	193	139	936	623	359
Ca	18593	8121	44	94	62	36
Mg	1264	282	22	23	16	9
S	1117	313	28	38	25	15
		Micro-Nutrients				
Mn	677.9	115.8	17	14	9	5
Fe	586.7	130.5	22	23	16	9
Cu	5.549	1.420	26	32	22	13
Zn	22.78	6.05	27	35	24	14
		Plot 68-50 0_1				
		Macro-Nutrients				
N	11950	1838	15	11	7	4
P	1099	126	11	6	4	2
K	244	231	95	437	291	168
Ca	22818	4190	18	16	10	6
Mg	1785	164	9	4	1	1
S	1658	307	18	16	10	6
		Micro-Nutrients				
Mn	1552	314	20	19	13	7
Fe	578.0	54.7	9	4	1	1
Cu	6.503	0.765	12	7	5	3
Zn	46.40	6.82	15	11	7	4

[1] n = 12

[2] Coefficient of varaition (C.V.) = $\frac{\text{Standard deviation}}{\text{mean}} \cdot 100\%$

[3] Number of samples = $\frac{t^2 \ (\text{C.V. } \%)^2}{(\text{Allowable Error})^2}$ = Allowable Error = 10% of mean

greatest, slopes were steepest and the area was dissected by a small ravine in which litter accumulated. In contrast, plot 68-50 was on a uniform slope of five percent steepness. The differences in C.V.s and sample sizes required to describe 0_1 and 0_2 horizon were maintained between these plots even as samples taken were increased.

The large numbers of samples required to describe the biomass of the 0_2 horizons at the 95 percent (and 90% in plot 68-50) confidence interval are spurious. For the plot size used in this study, 1600 $\frac{1}{4}m^2$ samples provide 100% coverage. When estimates of variance were based on only two samples, t for 95% confidence interval was large and the coefficient of variation was often large which together produced unrealistic estimates. The absence of 0_2 at some locations, relatively thick accumulations in small pockets nearby, and difficulties in separating thin layers of 0_2 from the mineral A, soil made sampling especially difficult in these forests.

Several authors have shown that K is highly mobile (Gosz et al., 1973; Gosz et al., 1976; and Rohlf et al., 1978). This may be the reason that K required the greatest estimated number of samples. Also plot 66-51 nutrients required more samples at each level of precision. This may be due to the species differences between the plots and different nutrient concentrations (Grizzard et al., 1976). These species nutrient concentration differences may be retained as decomposition proceeds (Gosz et al., 1973 and Witkamp, 1969).

It is important to realize that an acceptable level of sampling for one nutrient may not give acceptable results for another. For example if one chose a sampling intensity on the basis of P variability in (estimated n = 6) plot 68-50 to estimate the number of samples required, only Mg (n = 4) would be adequately estimated. In addition the other nutrients N (n = 11), K (n = 437), Ca (n = 16), S (n = 16), Mn (n = 19) and Zn (n = 11) would not be estimated at the required level of precision. One must choose which attributes are important and sample accordingly. Acceptance of lower precision levels or larger errors for other attributes may be necessary.

At what level should one sample? The formula for calculating the estimated number of samples required may be misleading because a large part of the reduction in the estimated number of samples comes from the reduction

in the t value, not necessarily from a better estimate of the variance. If the C.V. tended to fluctuate at smaller sample sizes, but changed little at larger sample sizes, the sample number at which the C.V. begins to change little may be the minimum sample size required.

It is also apparent that serious consideration must be given the allowable error and level of precision which are actually required by the research objectives. In these forests, expense of obtaining estimates of most forest floor atributes with small errors and at high confidence levels is high. In many cases, harvesting 25 percent or more of the detritus in the plot would be required. For example, in the plots studied, if errors of 20% and 30% of the mean were allowable, sample size could be reduced to about one-fourth and one-tenth, respectively, of sizes indicated for 0_1 and 0_2 biomass estimate.

CONCLUSIONS

One must decide which horizon, nutrients, or nutrient group is most important with respect to research objectives and then adjust sampling intensities accordingly; a single level of sampling intensity will not be optimum for all attributes. Estimating required sample size from small numbers of preliminary samples may give spurious results in these forests when small errors and high precision are required. Increasing the number of preliminary samples taken may reduce estimates of variability and is necessary to obtain accurate information for calculating final sample size in the plots studied. Inherent departures from normal distribution by several forest floor attributes further necessitate basing estimates of final sampling intensity on several preliminary samples. In these forests obtaining estimates with 10% error and 95% precision will require harvesting of between 4 and 936 $\frac{1}{4}m^2$ samples/0.04 ha plot, depending on the forest floor attribute.

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