Depth, weight, and water storage of the FOREST FLOOR in white pine stands in Massachusetts

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Depth, weight, and water storage of
THE FOREST FLOOR
in white pine stands in Massachusetts[1]

■

A LOOK AT THE FOREST FLOOR

FOR MOST forest types we know very little about the forest floor and how well it stores water. This is true for the white pine type in the Northeast, so we undertook a study to gather information about the depth and weight of the forest floor as well as the content of organic matter in the floor under white pine (*Pinus strobus, L.*) stands. Other aims were to find out why the forest floor accumulates more in some areas than in others and how the water-storage capacity of the forest floor can influence floods.

[1]A contribution of the Department of Forestry and Wildlife Management, Experiment Station, College of Agriculture, University of Massachusetts, in cooperation with the Northeastern Forest Experiment Station, Forest Service, U. S. Department of Agriculture. Support for this study came from cooperative aid funds of the U. S. Forest Service, Regional Research Project NE-27, and Massachusetts Experiment Station Project Hatch 78.

METHODS

In our study we took two sets of measurements: (1) the physical nature of the forest floor, and (2) the moisture content and drying rate of the forest floor.

First we measured the depths of forest floors under white pine stands in Massachusetts, and weighed their organic matter content. We took samples from 65 ⅒-acre plots (fig. 1).

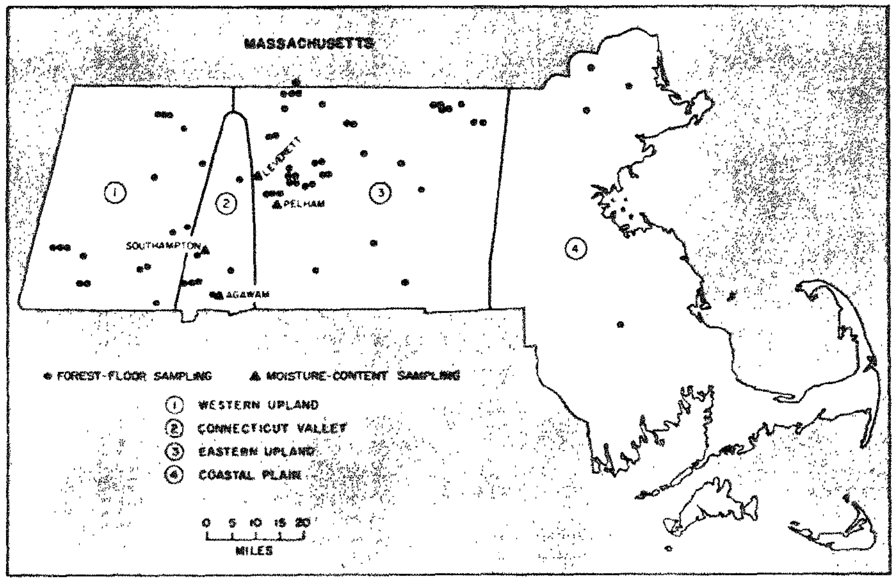


Figure 1.—Location of sampling plots and geographic provinces.

Sampling was done in summer 1962 and 1963. At each plot two 1-square-foot areas of the forest floor were sampled.[2] Samples were separated by layers on the basis of these generally accepted divisions: L for undecomposed needles and twigs, F for partially decomposed organic matter but recognizable as to origin, and H for humified, well-decomposed organic matter. Then the samples were air-dried and weighed. Oven-dry weight

[2]The term forest floor as used here includes the superficial organic layers lying above the mineral soil.

(at 103°C.) and organic-matter content (loss on ignition in a muffle furnace at 600-700°C.) were determined on subsamples.

No recent cutting, grazing, or fire was evident on any of the 65 plots. Stands ranged in age from 34 to 96 years, in basal area from 92 to 309 square feet, and in site index (height of dominants and co-dominants at 50 years) from 47 to 80 feet. By major geographic provinces, 17 of the plots were located in the Western Upland, 7 in the Connecticut Valley, 37 in the Eastern Upland, and 4 in the Coastal Plain (fig. 1). Plot elevations ranged from 25 to 1,440 feet. Twenty-seven plots were located on deep sands and gravels, 10 on aeolian or water-laid mantle over coarse subsoil, 4 on coarse-textured tills generally with no pan, 23 on fine-textured tills generally with a pan, and 1 on peat. As to drainage, 3 plots were very poorly or poorly drained, 5 somewhat poorly drained, 9 moderately well-drained, 33 well-drained and somewhat excessively drained, and 15 excessively drained. The characteristics of each plot are given in table 1 (Appendix).

In the second part of the study, moisture contents and drying rates of the forest floor layers were measured at four areas (fig. 1). Two areas in central Massachusetts were sampled at intervals of 1 to 3 weeks from April to November 1963. One of these, in the town of Leverett, consisted of a dense stand approximately 65 years old, 55 feet in height, and 181 square feet per acre in basal area. The other, 5 miles distant, in the town of Pelham, was a plantation about 46 years old, 54 feet in height, and 203 square feet per acre in basal area. By means of a small wooden frame, four 6-inch sections of the forest floor were removed at each sampling. Separated layers of each sample were placed in plastic bags to prevent moisture loss, then were taken to the laboratory where they were weighed, oven-dried, and analyzed for moisture content and organic matter.

In April and May 1964, we took weekly samples on these two areas and on two additional areas in southwestern Massachusetts, one in the town of Southampton and the other 10 miles away in the town of Agawam. The stand in Southampton was about 72 years old, 71 feet in height, and 256 square feet per acre in basal area; the one in Agawam was about 40 years in age, 48 feet in height, and 170 feet per acre in basal area. An improved sampling frame with heavy vertical wires attached was used (fig. 2). The wires stabilized both the wooden frame and the organic materials when the layers were cut and removed inside the frame.

We estimated maximum storage capacities from representative recurring maxima and minima on the four study areas; then we tabulated the data in moisture percentage by weight and by volume for the L, F, and H layers. The four lowest and highest values were used, except in three cases where the fourth value was inconsistent and therefore was not included. Moisture contents by volume were based on the measured humus thickness for each sampling point.

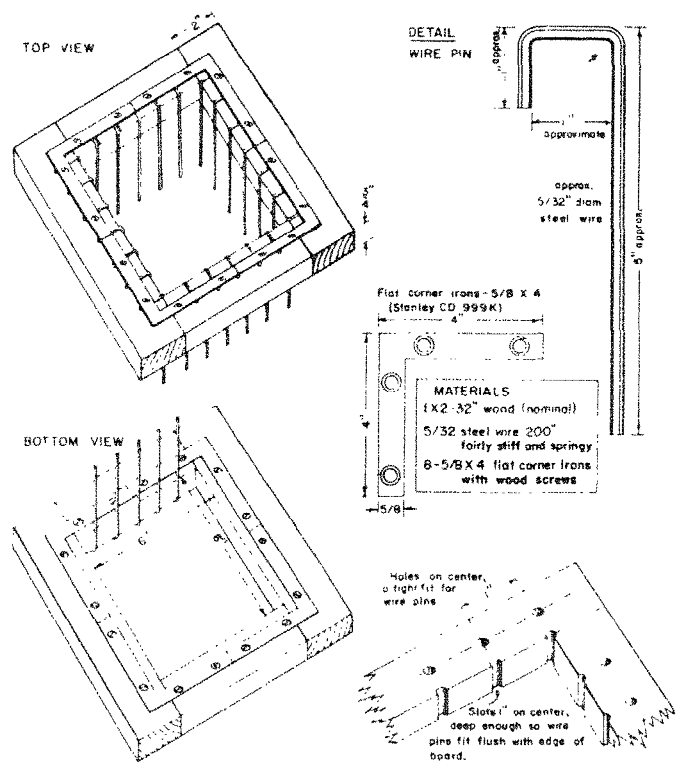


Figure 2.—Frame for sampling forest floor.

Weights of the forest-floor samples as well as the contents of organic matter and moisture of the four areas were analyzed for sampling errors. Standard errors of 4-sample means for the entire forest floor were about 5,000 pounds per acre—equivalent to confidence limits (at the 95-percent level) of about 30 percent of the mean. Mean moisture contents in inches of water, based on 4 samples, had confidence limits of about 30 to 80 percent of the mean. For extended discussion of sampling errors by locations and layers see the Appendix.

In this paper, we give first the mean accumulations of all plots in inches of thickness and weight by layers and by total amounts. Next we analyze differences in accumulations by geographic provinces and by soil-parent materials to show the influence of regional patterns of climate and soil. Then we give bulk densities of the forest-floor layers followed by: correlations and regressions of thickness of the various layers to their weights, along with correlations of forest-floor weights to organic-content weights and correlations of thickness between layers and weights between layers; simple and multiple correlations and regressions of forest floor and organic-matter accumulations on age, basal area, site index, elevation, and soil-drainage class for the 65 stands. Finally, we estimate moisture storage of the forest floor and daily drying rates and discuss the possible effects of these factors on floods.

RESULTS AND DISCUSSION

Mean Accumulation for All Plots

Forest floors averaged 2.5 inches deep and 20 tons per acre oven-dry weight, of which 13 tons were organic matter and 7 tons were mineral matter and ash. Measurements of similar magnitude in predominantly white pine have been found elsewhere in New England, New York, Pennsylvania, and Minnesota (Appendix, table 3).

The L layer of all plots averaged 0.69 inch thick and ranged from 0.3 to 1.5 inches; the F layer 1.25 inches; ranging from 0.3 to 2.1 inches; the H layer 0.52 inch, ranging from 0 to 1.6 inches. The total thickness of the forest floor averaged 2.46 inches and ranged from 0.6 to 4.7 inches. The L layer made up to 28 percent of the total thickness, the F layer 51 percent, and the H layer 21 percent.

Average oven-dry weights and ranges in pounds per acre of the forest floor and organic matter by layers were:

	Forest floor	
Layer	*Average*	*Range*
L	3,700	1,700 to 12,500
F	20,500	7,500 to 35,100
H	16,900	0 to 63,600
Total	41,000	10,200 to 85,800

	Organic Matter	
Layer	*Average*	*Range*
L	3,500	1,600 to 11,700
F	16,000	3,800 to 29,000
H	6,500	0 to 18,500
Total	26,000	6,000 to 46,400

On a weight basis, the L layer made up 9 percent of the forest floor and 13 percent of the organic matter; the F layer 50 percent of the forest floor and 62 percent of the organic matter; and the H layer 41 percent and 25 percent, respectively. Thus the F layer was the dominant feature of the forest floor. Mineral content was negligible in the L layer, averaging about 5 percent, and relatively small in the F layer, averaging 22 percent; but it was large in the H layer, averaging 62 percent.

Accumulations by Geographic Provinces

Mean total accumulations by geographic provinces were:

	Forest Floor		*Organic matter*
Provinces	*Depth (in.)*	*Weight (lbs./acre)*	*Weight (lbs./acre)*
Western Upland	2.11	36,600	21,000
Connecticut Valley	2,69	34,300	25,300
Eastern Upland	2.57	43,700	27,900
Coastal Plain	2.55	50,600	30,800

From analyses of variance, differences between provinces in forest floor depths and weights were not significant at the 5-percent level (F for depth = 2.05, for weight 1.60, for 5-percent level 2.76). Differences in organic matter were significant at the 5-percent level (F = 3.21). And compared for individual provinces, organic matter differences between the Western and Eastern Uplands and between the Western Upland and Coastal Plain proved to be significant at the 5-percent level.

Accumulations by Parent Materials

Mean total accumulations by parent materials were as follows:

	Forest floor		*Organic matter*
	Depth (in.)	*Weight (lbs./acre)*	*Weight (lbs./acre)*
Sands and gravel	2.59	48,300	29,000
Aeolian or fine-textured outwash	2.50	39,200	26,900
Coarse-textured till	2.05	36,300	17,000
Fine-textured till	2.37	34,400	23,600

Differences between forest-floor depths, from an analysis of variance, were not significant at the 5-percent level (F = 0.96). But differences between forest-floor weights were significant (F = 3.87) as were differences in organic matter weights (F = 3.51); in both analyses the significant difference (5-percent level) was between sands-and-gravel and the fine textured tills, and also for organic matter, between sands-and-gravel and coarse-textured tills.

Thickness, Weight, and Layer Relationships

Mean bulk densities of the total forest floor and its layer were:

L	0.024
F	.072
H	.144
L,F,H	.074

The F and H values are somewhat lower than mean values of 0.11 and 0.22, respectively, from several hardwood and conifer stands in the Northeast (*Trimble and Lull 1956*).

Correlations of forest floor thickness to forest floor weight by layers diminished from the L to H layers; simple correlation coefficients were:

L	0.675**
F	.611**
H	.589**
L,F,H	.570**

**Significant at the 1-percent level.

Linear regressions of predicted weight in pounds (Y) to depth in inches (X) and their standard errors of estimate (S.e.e.) were:

		S.e.e.
L	Y= 5,296X	1,465
F	Y=15,838X	5,761
H	Y=28,551X	11,708
L,F,H	Y=16,474X	13,532

For plots in this study, depths provided only poor estimates of weights: standard errors of estimate ranged from about one-fourth to over one-half of average weights of the layers.

Correlation of forest floor weights to organic-matter weights by layers also diminshed with depth:

L	0.997**
F	.967**
F	.765**
L,F,H	.754**

Predicted organic content weights (Y) in relation to forest floor weight (X) and their standard errors of estimate were:

		S.e.e.
L	Y=0.95X	164
F	Y= .78X	3,740
H	Y= .34X	3,248
L,F,H	Y= .60X	6,618

For plots such as these, organic-matter content of the litter and the total forest floor were estimated fairly well from forest floor weights, the greatest error being in relation to mean layer weights was in the H layer.

Because of the fluctuating nature of the L layer, we did not compute correlations of thicknesses and weights between the

L and F layers. Correlations between the F and H layers were weak and not significant; thickness or weight of these layers could not be estimated from each other.

Influencing Factors

By simple correlation, we calculated the relationships of age, basal area, site index at 50 years, elevation, and soil drainage class to total accumulations of forest floor and organic matter. These factors were selected as those most likely to reflect stand, climate, and soil conditions influencing both production and decomposition of the humus layers. Simple correlation coefficients were:

	Forest floor		*Organic matter*
	Depth	*Weight*	*weight*
Age	0.334**	0.417**	0.313**
Basal area	.012	–.068	–.083
Site index	–.242*	–.306*	–.391**
Drainage class	.136	.374**	.226
Elevation	–.203	–.218	–.261*

*Significant at the 5% level.

Only age and site index were significantly related to all three of the accumulative variables. Correlations were not strong, age and site index individually accounting for only 6 to 17 percent of the variations in accumulation.

The positive correlation with age was as expected. The negative correlation with site index is supported by recent observations by the senior author that small amounts of forest floor of red pine plantations were associated with better sites. Young (*1954*) and Trimble (*Trimble and Lull 1956*) have also noted thick accumulations of more humus layers on poor sites and smaller amounts on better sites, either because of more rapid decomposition or incorporation. However, as noted by Kittredge (*1948*), others have reported positive correlations between site index and amount of forest floor.

Drainage class was significantly related only to forest floor weight, drier soils having greater accumulation. These dry soils also generally registered somewhat lower site quality. It seems likely that wet soils (poorly and very poorly drained) might show large accumulations also, but only one wet-soil stand showed a larger accumulation. The negative correlations with elevation may be related to the fact that poorer sites on sandy, gravelly soils in Massachusetts are generally found at lower elevations; however, the correlation of 0.107 between site index and elevation for these plots provided little support for this hypothesis.

The small proportion of the variation in total accumulation accounted for by the above independent variables suggested that one of the forest floor layers might be more highly correlated. To determine this, simple correlation coefficients were computed between each layer and each of the 5 independent variables (Appendix, table 5). Of the 45 correlation coefficients, only 8 were significant:

	Forest floor				
	Depth		*Weight*	*Organic matter*	
	F	*H*	*H*	*F*	*H*
Age	0.261*	0.311*	0.355**	0.290*	—
Basal area	—	—	—	—	–0.244*
Site index	—	—	—	–.256*	—
Drainage class	—	—	.298*	—	—
Elevation	–.367*	—	—	—	—

The L layer was not significantly correlated to any of the stand or environmental variables. Stand age accounted for 4 of the 8 significant coefficients. Generally, thicknesses or weights of individual layers were not as highly correlated as total values.

Multiple Regressions

Multiple regressions were calculated, relating the five site variables to forest floor (Y_1) and organic matter (Y_2) weights:

$$Y_1 = 36.081 + 3.83X_1 - 6.51X_2 - 1.76X_3 - 0.82X_4 + 2.93X_5$$
$$Y_2 = 43.104 + 1.56X_1 - 1.84X_2 - 3.35X_3 - 0.51X_4 + 0.38X_5$$

In these equations X_1 = average stand age divided by 10; X_2 = basal area in square feet per acre divided by 100; X_3 = site index divided by 10; X_4 = elevation in feet divided by 100; X_5 = drainage class[3]; Y_1 and Y_2 are in thousands of pounds.

Multiple correlation coefficients 0.589** for the forest floor and 0.535** for the organic-matter equations, though significant at the 1-percent level, are still relatively low—the highest accounting for only about 35 percent of the variation in the dependent variable. The low percentage of variability accounted for suggests that some important major factors may not have been included; also, the large natural variation and consequent sampling errors were partially responsible for the low percentage.

Two variables in each regression, age and drainage class in the forest-floor equation and age and site index in the organic-matter regression, proved in t-tests to be statistically significant. The nature of these factors suggests that they act independently in relation to accumulations.

As a matter of interest, we calculated multiple regressions, employing only the three variables that had proved to be significant in simple correlation. And we calculated separate regressions for the 27 plots on fine-textured tills; a multiple regression with weight of the H-layer as the dependent variable was calculated. Correlation coefficients are summarized as:

Dependent variables	*Independent[4] variables*	*Forest floor*	*Organic matter*
L,F,H,	A,B,S,D,E	0.589**	0.535**
L,F,H,	A,S,D	.534**	—
H	A,S,D	.445	—
L,F,H	A,S,E	—	.525**
L,F,H sand-gravel	A,B,S,D,E	.560**	.707**
L,F,H tills	A,B,S,D,E	.440**	.476**

Correlation coefficients were not greatly reduced by employing three variables rather than five; the H-layer weight was not as highly correlated as total weight of the forest floor; and plots on sands and gravel yielded highest correlations.

[3] O = very poorly drained, 1 = poorly drained, 2 = somewhat poorly drained, 3 = moderately well drained, 4 = well drained, 5 = somewhat excessively drained, 6 = excessively drained.

[4] A = age, B = basal area, S = site index, D = drainage class, and E = elevation.

Moisture Storage and Drying

Moisture contents, taken periodically at the four sampling sites, are shown in percent by weight in figure 3 and in inches of water in figure 4. Mean maxima and minima, by layers for each of the four sampling areas, are tabulated in the Appendix, table 6, together with the composite averages for all plots. The values are reasonably consistent for all stands.

Maximum moisture observed in the L layer ranged from 124 to 291 percent by weight, averaging 169. Most values ranged from 150 to 170 percent. In percent by volume, the values ranged from 4.0 to 8.3 percent; however, these values were not very reliable because of the difficulty in measuring the L-layer thickness accurately. Minimum values for the L layer ranged from 5.2 to 14.8 percent by weight, averaging 9.5. Thus the maximum absorptive capacity was about 160 percent by weight for the L layer. By volume it was about 5.5 percent.

Values for the F layers followed a similar pattern: maxima by weight ranged from 222 to 318 percent, averaging 258. Minima ranged from 15 to 44 percent by weight, averaging 30. By volume, maxima ranged from 14 to 33 percent, averaging 21, while minima ranged from 1.2 to 3.5 percent, averaging 2.3. These values indicate the high maximum, moisture-holding capacity of F layers: about 230 percent by weight or 18 percent by volume.

Values for H layers were more variable than for L and F layers because of the wide variation in mineral content that caused large fluctuations in the percent-by-weight values. The absorptive capacity of about 24 percent by volume (the difference between an average maximum of 31 percent and an average minimum of 6.5 percent), was even higher than for the F layers.

Maximum moisture content for the total forest floor averaged 205 percent by weight, and the minimum moisture content averaged 27 percent. These were very similar to comparable values of 220 percent and 25 percent reported by Metz (*1958*) for loblolly pine forest floor in South Carolina, and 215 percent and 30 percent reported by Helvey (*1964*) for hardwood forest floor in North Carolina.

Maximum and minimum water-holding capacities of the layers in the four stands, in inches of water, are given in table 1. The differences between minimum and maximum values for the four stands ranged from 0.39 to 0.46 inches of water for the total forest floor. This amount represents the maximum amount of rain that might be retained by the layers if they were in field-dry condition.

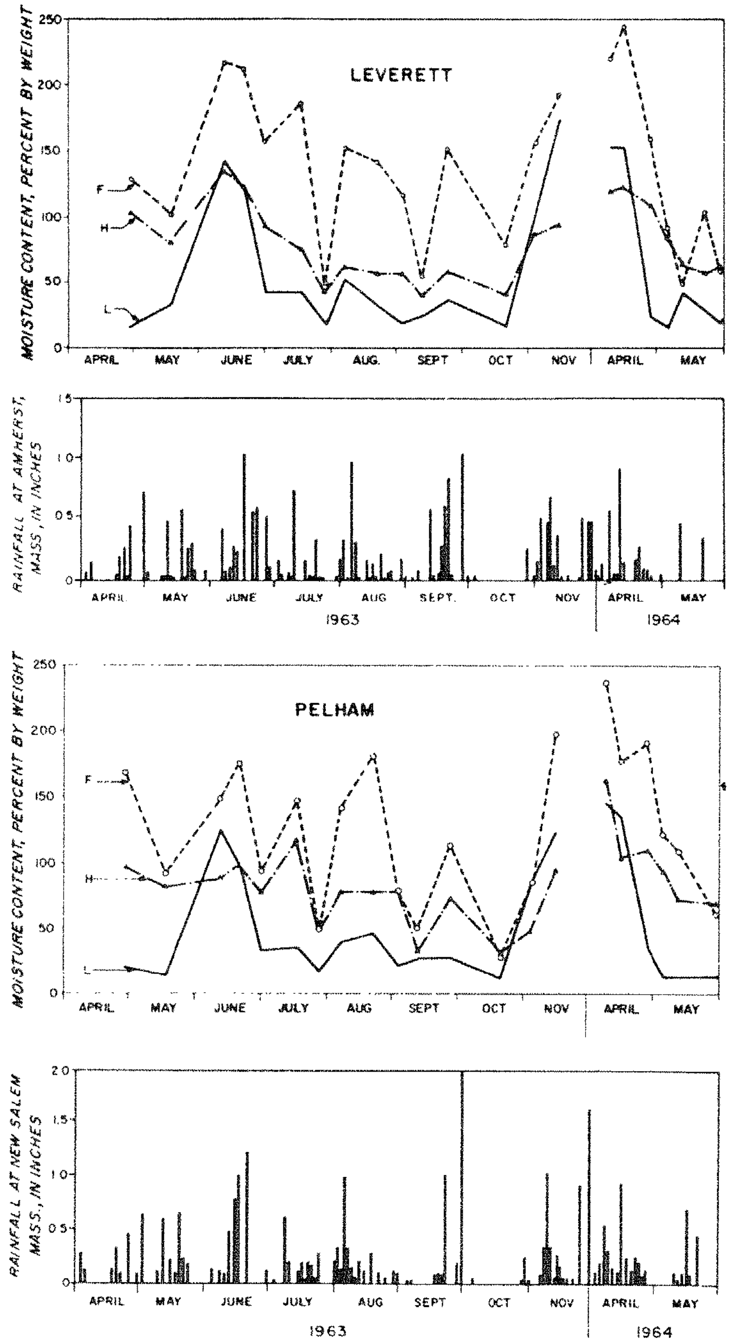
Based on a maximum moisture content of 0.45 inch at Leverett and 0.51 at Pelham, the mean available storage for the 1963 period was 0.22 inch and 0.28 inch respectively. The comparable mean available soil-moisture storage was 2.05 inches, based on a soil-moisture budget with an estimated 4.0 inches total of maximum available storage. On this basis, forest-floor storage constituted about one-ninth of the total available soil-moisture storage. Available forest-floor storage for the days of measurement and comparable available soil-moisture storage are given in figure 5.

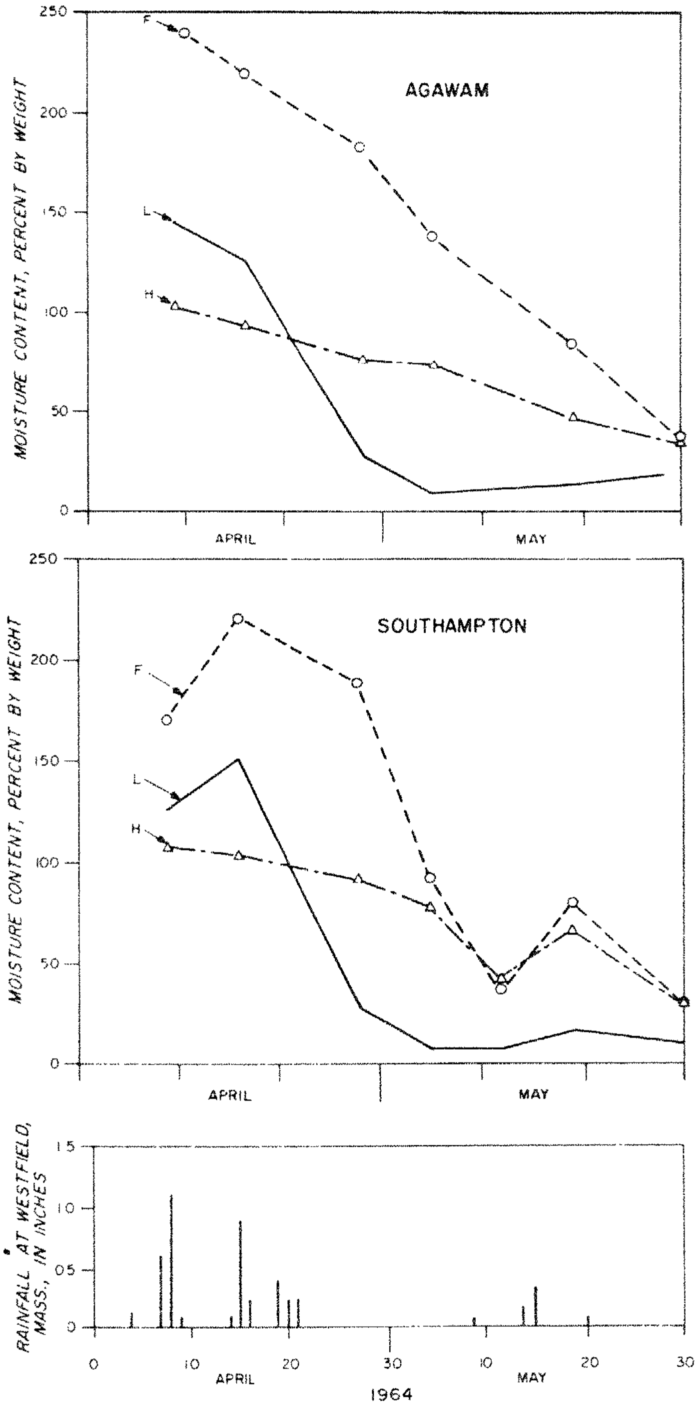
The mean available storage of about 0.25 inch during the summer months plus canopy interception of about 0.10 inch (for 0.5 inch of rainfall) could absorb many of the smaller rainfalls. For instance, from May to October about 60 storms occur (based on the 1952-61 record) of which 45 to 75 percent are 0.50 inches or smaller. They account for about one-third of the 6-month rainfall. Many of the smaller storms could be absorbed almost completely by interception of canopy and humus.

Drying rates differed appreciably among the L, F, and H layers, as is evident in figures 3 and 4: the F layers dried more rapidly than the H; the L layers, presumably, dried more rapidly than the F, though sampling periods were too infrequent to show this. Total exchange of moisture also varied by layers. During the 6-month period in 1963, for instance, inches of moisture accretion and depletion were:

	L		*F*		*H*		*LFH*	
	+	—	+	—	+	—	+	—
Leverett	0.08	0.04	0.42	0.35	0.16	0.17	0.60	0.51
Pelham	.07	.04	.72	.55	.32	.31	1.05	.85

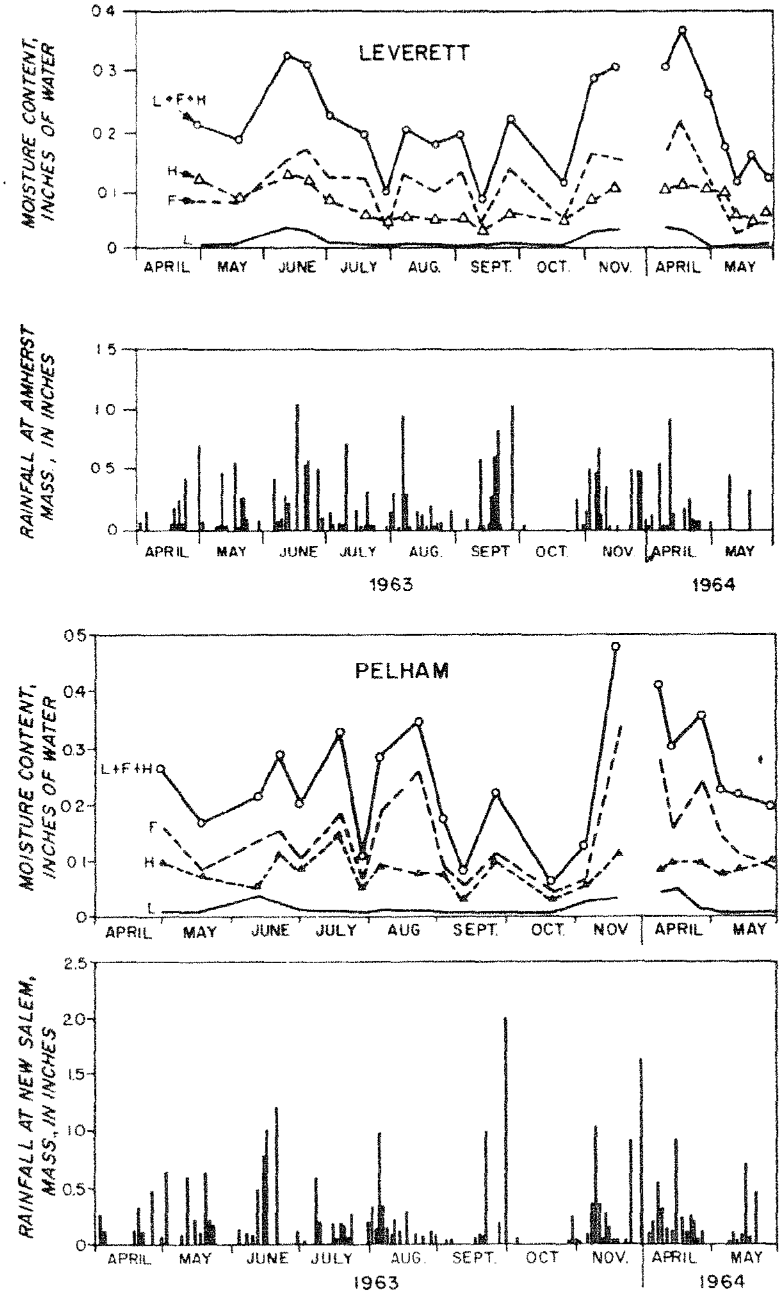
Figure 3.—Moisture content of the forest floor in percent by weight, by location, layer, and date.

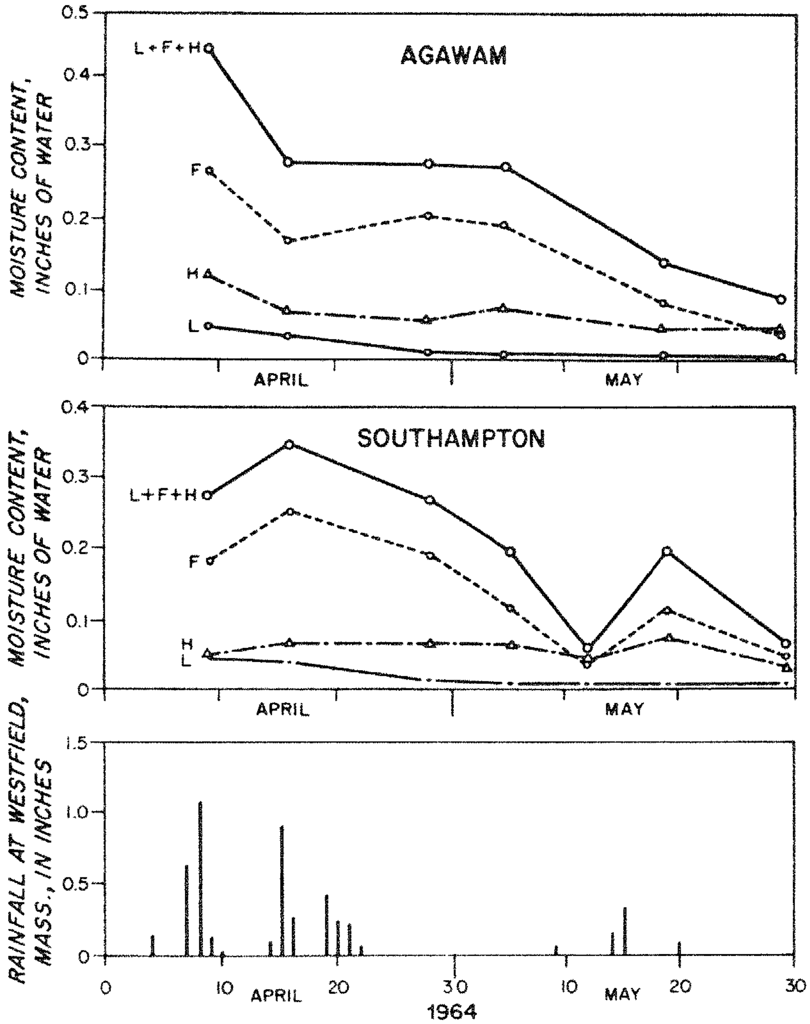




AGAWAM
MOISTURE CONTENT, PERCENT BY WEIGHT
250
200
150
100
50
0
F
L
H
APRIL
MAY
SOUTHAMPTON
MOISTURE CONTENT, PERCENT BY WEIGHT
250
200
150
100
50
0
F
L
H
APRIL
MAY
RAINFALL AT WESTFIELD, MASS., IN INCHES
1.5
1.0
0.5
0
0
10
20
30
10
20
30
APRIL
MAY
1964

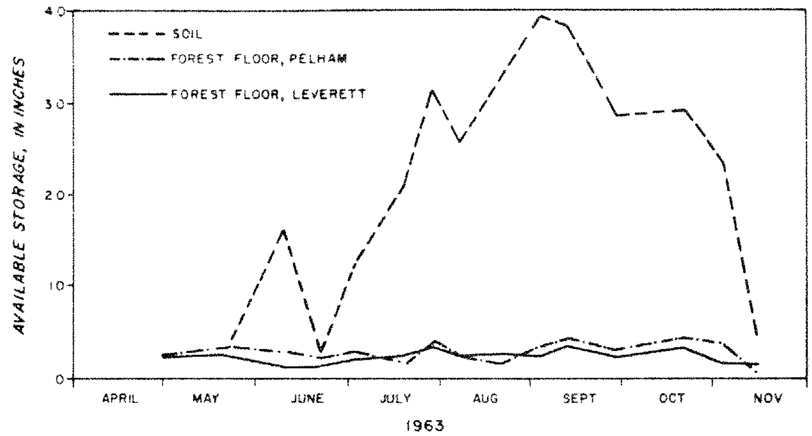
Figure 4.—Moisture content of the forest floor in inches of water, by location, layer, and date.





AGAWAM
L+F+H
F
H
L
MOISTURE CONTENT, INCHES OF WATER
0.5
0.4
0.3
0.2
0.1
0
APRIL
MAY
SOUTHAMPTON
0.4
RAINFALL AT WESTFIELD, MASS., IN INCHES
1.5
1.0
0.5
0
10
20
30
1964

Figure 5.—Available storage in forest floor and soil on sampling dates from May to November 1963.



Thus the F layer dominated the other two layers both in respect to its magnitude (as previously noted) and in its moisture exchange.

The 6-month growing-season loss of about 0.75 inch suggests an annual loss of 1.0 to 1.25 inches, about one-half the 2-inch annual loss in the southern Appalachians *(Helvey and Patric 1965)*.

Partial wetting of the forest floor took place readily; but complete resaturation required, as Metz (*1958*) found, an extended period of heavy rainfall (figs. 3 and 4). Only a small portion of many rainfalls is absorbed even though the forest floor is not completely saturated. Absorptions of 0.1 to 0.25 inch of rain occurred during rainy periods in the summer but resaturation to the 0.4- to 0.5-inch capacity did not occur even with rains of 1 to 2 inches. Apparently either a good deal of high-intensity rain moves through the layers too rapidly to be absorbed, or the moisture does not have easy access to all absorption surfaces, or some material does not rewet easily once dried.

L layers did not rewet easily during the summer; generally moisture contents stay at very low levels during these months, never approaching the late-fall levels. The L layers did resaturate in the rather extended rainy period in June, 1963. F layers rewetted much more readily, rewetting—even at the lower moisture contents—to quite high levels during the summer rains. H layers did not rewet as readily as F layers.

FOREST FLOOR AND FLOODS

The hydrologic significance of moisture storage in the forest floor in respect to floods can be evaluated only in relation to available storage and the amount of flood-producing rainfall. The amount of storage will depend on antecedent drying. Drying rates of the total forest floor are given in table 2 for those periods in which drying was least affected by rainfall. Estimated rates of soil-moisture drying, based on a daily soil-moisture budget calculated by Thornthwaite's and Mather's procedure (*1957*), are also given. Mean values suggest that during these periods daily loss from the forest floor is about one-fifth of the potential loss.

Synthesizing the eight drying periods into a single curve, on the basis of initial moisture contents, gave a mean curve with these drying rates of the forest floor:

Days	*Loss per day (inches)*
1- 5	0.024
6-10	.016
11-15	.014
16-20	.010

Potential opportunities for antecedent drying of the forest floor and soil, based on the above drying rates and the mean annual number of drying periods of various lengths, May to October, are given in table 3. On an average, only about twice a year would as much as 0.30 inch of moisture be removed between storms—equivalent, depending on initial moisture content, to an available storage of about 0.30 to 0.40 inch. Compared with flood-producing rainfalls, this is a small amount. For instance, characteristic rainfall for severe floods in Massachusetts is around

10 inches in 24 hours over a 200-square-mile area. (*U. S. Department of the Army 1952*). At this intensity of rain, forest-floor storage could then account for 3 to 4 percent of the total, but whether it could reduce the amount of flood runoff by this amount would depend on the available storage of alternative land-uses. From this, apparently, the forest floor of white pine stands in Massachusetts would have very little effect on the volume of runoff yielded from flood-producing rainfalls during the growing season. During the dormant season, when the forest floor would be wetter, its effect on flood volumes would be even less.

Would greater amounts of forest floor be accumulated under older stands of white pine? Measurements suggest this; accumulations in pounds per acre by 10-year age classes were as follows:

Age classes (years)	*All plots*	*Sand & gravel plots*	*Till plots*
31-40	34,400	39,100	26,400
41-50	35,700	46,600	32,200
51-60	44,000	46,200	—
61-70	44,600	50,800	—
71-80	42,100	—	40,200
81-90	63,200	63,200	—
91-100	58,500	55,600	—

Maximum accumulations appear in the 81- to 90-year-old class and are about one-third greater than accumulations at 55 years, the average age of the 65 stands. Even so, this difference, in terms of available water storage, would not amount to much more than 0.10 inch, a difference not great enough to change the above conclusions.

The principal hydrologic function of the forest floor is to permit ready entry of rainfall into the soil. The forest floor's high infiltration rate and its protection of the mineral soil below (both stabilizing it and fostering high percolation rates) give it an importance long recognized. Lowdermilk noted in 1930 that the forest floor is far more important for maintaining percolation capacity than for absorption of rainfall. We did not measure infiltration in this study; but there was no evidence of overland flow or erosion where a forest floor had accumulated.

The role the forest floor plays in flood prevention is a relatively minor one for the forest as a whole. The greatest role of the forest is in the available storage it creates in the soil through transpiration. The greater vegetation of the mature undisturbed forest in relation to other land uses, and its deep root system and low albedo, permit maximum development of available storage for flood-producing rainfalls. This effect on flood runoff, however, can only be evaluated in respect to effects of alternative land uses.

SUMMARY

The principal results of this study are:

- The forest floor of 65 white pine stands in Massachusetts averaged 2.5 inches in depth and weighed about 20 tons per acre, of which 13 tons were organic matter.
- The L layer averaged 0.69 inches in thickness, the F layer 1.25, and the H layer 0.52.
- There was a significant difference in organic matter accumulations between the Eastern (27,900 pounds per acre) and Western Uplands (21,000 pounds per acre) and between the Western Upland and the Coastal Plain (30,800 pounds per acre). Difference in forest floor accumulations were not significant.
- Sands and gravels had significantly greater accumulations of forest floor (48,300 pounds per acre) and organic matter (29,000 pounds per acre), than the fine-textured till soils (34,400 and 23,600 pounds per acre, respectively).
- Correlation coefficients of depths to weight of forest floor layers ranged from 0.675** to 0.570**. Correlation of forest floor weights to organic-matter weights ranged from 0.997** to 0.750**. There was little or no correlation between thicknesses of the F and H layers and their weights.
- Multiple regression equations with five independent variables (age, basal area, site index, drainage class, and elevation)

accounted for 30 to 35 percent of the variation in weight of the forest floor and organic matter. Age, site index, and drainage class were the most important variables.

- Maximum moisture storage capacity of the forest floor at four sampling areas ranged from 0.39 to 0.46 inches. The mean daily drying rate for periods least affected by rainfall was 0.014 inch, about one-fifth of the mean daily potential evapotranspiration.
- The forest floor did not resaturate during the summer months, even from rainfalls that exceeded moisture-storage capacities.
- Mean available storage in the forest floor, from May to November 1963, was about 0.25 inch.
- On an average, only about twice a year would as much as 0.30 inch of moisture be removed from the forest floor between storms.
- Forest floor storage could accommodate perhaps 3 to 4 percent of the 10-inch rainfall that produces severe floods in Massachusetts.
- About 20 to 25 forest floor samples are necessary to give mean weights with standard errors that, within 95-percent confidence limits, are equivalent to 10 to 15 percent of the mean; a similar number of moisture-content samples will give means with errors of about 20 to 25 percent.

LITERATURE CITED

Alway, F. J., W. J. Methley, and O. R. Younge.
1933. DISTRIBUTION OF VOLATILE MATTER, LIME, AND NITROGEN AMONG LITTER, DUFF, AND LEAFMOLD UNDER DIFFERENT FOREST TYPES. Soil Sci. 36: 399-407.

Cline, A. C., and S. H. Spurr.
1942. THE VIRGIN UPLAND FOREST OF CENTRAL NEW ENGLAND. Harvard Forest Bull. 21. 58 pp., illus.

Day, Gordon M.
1940. TOPSOIL CHANGES IN CONIFEROUS PLANTATIONS. J. Forestry 38: 646-648.

Helvey, J. D.
1964. RAINFALL INTERCEPTION BY HARDWOOD FOREST LITTER IN THE SOUTHERN APPALACHIAN. U. S. Forest Serv. Res. Paper SE-8. 9 pp. SE. Forest Exp. Sta., Asheville, N. C.

Halvey, P. D., and J. H. Patric.
1965. CANOPY AND LITTER INTERCEPTION OF RAINFALL BY HARDWOODS OF EASTERN UNITED STATES. Water Resources Res. 1: 193-206.

Kittredge, Joseph.
1948. FOREST INFLUENCES. 394 pp. McGraw-Hill, New York.

Lowdermilk, W. C.
1930. INFLUENCE OF FOREST LITTER ON RUN-OFF, PERCOLATION, AND SOIL EROSION. J. Forestry 28: 474-491.

Lull, Howard W.
1959. HUMUS DEPTH IN THE NORTHEAST. J. Forestry 57: 905-909, illus.

Lunt, Herbert A.
1932. PROFILE CHARACTERISTICS OF NEW ENGLAND FOREST SOILS. Conn. Agr. Exp. Sta. Bull. 342, 743-846, illus.

Metz, Louis J.
1958. MOISTURE HELD IN PINE LITTER. J. Forestry 56: 36.

Morey, H. F.
1942. THE APPLICATION OF OUR KNOWLEDGE OF THE ORGANIC LAYERS OF THE SOIL PROFILE TO FLOOD-CONTROL. Pa. State Coll. Sch. Engin. Tech. Bull. 27: 143-151.

Thornthwaite, C. W., and J. R. Mather.
1957. INSTRUCTIONS AND TABLES FOR COMPUTING POTENTIAL EVAPOTRANSPIRATION AND THE WATER BALANCE. Drexel Inst. Tech. Lab. Climatology, In Climatology 10: 185-311.

Trimble, G. R., Jr., and Howard W. Lull.
1956. THE ROLE OF FOREST HUMUS IN WATERSHED MANAGEMENT IN NEW ENGLAND. U. S. Forest Serv. NE. Forest Exp. Sta., Sta. Paper 85. 34 pp., illus.

United States Department of the Army.
1952. STANDARD PROJECT FLOOD DETERMINATIONS. U. S. Dep. Army Civil Works Engin. Bull. 53-8.

Young, H. E.
1954. FOREST SOIL-SITE INDEX STUDIES IN MAINE. Soil Sci. Soc. Amer. Proc. 18: 85-87.

APPENDIX

Sampling Error

Thickness, weight, moisture content and organic content of the forest floor and its layers are characteristically quite variable and the number of samples needed to estimate them at specified levels of precision is unknown.

Towards this end, data from the Leverett and Agawam sites were analyzed for sampling variation. Standard deviations, coefficients of variations, standard errors, and confidence limits, for forest-floor and organic-matter weights, and moisture contents are given in table 2. Weights for all sampling dates were pooled, giving 24 to 32 replicates, on the assumption that weight changes were negligible over the period of sampling. Moisture-content averages were based on the four samples taken at each date so that replication was at a much lower level. Confidence limits at the 95-percent level were calculated for the various parameters on the basis of 4 and 24 or 32 samples in order to get an idea of precision at both levels.

The forest floor weight at Leverett was estimated quite precisely from 24 samples: on the order of ± 10 percent with only a 5-percent chance of larger error. The 32 samples at Agawam gave smaller errors in the L, F, and total, and a little larger error in the H layer. The error in the H layer weight was apt to be higher than other layers because of the inconsistent amount of mineral matter in the H layer, and the difficulty of judging the H layers boundary with the mineral soil below. Coefficients of variation of 18 and 22 percent were similar to the 20-percent coefficient reported by Helvey and Patric *(1965)* for hardwood forest-floor weights.

Organic-matter weights were no less variable. Coefficients of variation were somewhat higher, although of course they included the additional experimental error in subsampling and ignition of the samples. Confidence limits for means based on only four samples are on the order of 30 to 60 percent of the mean. In plots like these, 20 to 25 samples gave for most purposes satisfactory estimates of forest-floor and organic-matter weights.

The percentage of organic matter in the L and F layers was estimated quite precisely with only four samples — the L within ± 4 percent of the mean percent at the 95 percent confidence level, the F with a probable error of 11 percent of the mean value. The organic content of the H layer was more variable and required about 25 samples to be sure the estimate was as precise as that for the F layer. These data suggest that when sampling forest floor layers to determine total weight, it is necessary to sample much more intensively to estimate weights of the L and F layers than to determine their organic-matter contents. Therefore it is not necessary to run ignitions on all the samples obtained for the L and F layers, which is a definite saving in time and cost.

We anticipated that percentage moisture content of the forest floor would be more variable than its weight because of irregular drying and wetting. However, the data do not indicate that this was so; in fact, in many instances the reverse was true. Table 3 also indicates that percentages were least variable at high-moisture contents with 95-percent confidence limits of four sample averages for the L and F layers on the order of 10 and 25 percent of the mean value, and for the H layers up to about 50 percent. At low moisture contents, the errors in percentage of moisture ranged, with four samples, from 40 to 50 percent of the mean percent at the 95-percent confidence limit. Estimates suggest that sample numbers of about 25 will give moisture-percent means that are consistent within 5 to 10 percent of the mean value at high-moisture contents and within 10 to 15 percent at low-moisture contents in pine stands similar to these.

Estimates of total moisture content in inches of water for the forest floor, the value which is perhaps most important in this type of study, are much more variable than either weight or moisture percentage. Apparently both contribute substantially to the variation in total moisture content. Mean values based on four samples, the number taken in this study, had confidence limits at the 95-percent level of about 30 to 90 percent of the mean values. F layers seemed to be more variable in total-moisture content than the L or H layers. Increasing the number of samples to 24 would apparently bring the 95-percent confidence limits for the mean moisture content to within 20 to 25 percent of the mean values. Variability of the mean moisture content for the L, F, and H layers combined was lower than for the most variable horizon, usually the F layer, but not much lower. The variability of the estimation of total moisture contents in the humus layers was so high that we could seldom get means much more precise than ±10 percent at the 95-percent confidence level. Whether or not this precision can be greatly improved with other sampling designs remains to be seen, but it appears doubtful considering the variability in weight and the inconsistency of drying and wetting conditions from point to point.

Table 3.—*Mean annual number and length of drying periods and associated moisture loss from forest floor and soil*

Periods	Drying days	Moisture loss	
		Forest floor	Soil
No.	*No.*	*Inches*	*Inches*
10	1- 2	0.02-0.05	0.07-0.13
6	3- 4	.07- .10	.20- .27
5	5- 8	.12- .17	.34- .54
3	9-14	.18- .26	.60- .94
2	15-21	.27- .33	1.00-1.41

Table 1.—*Maximum and minimum moisture contents of forest floor layers in four white pine stands, and maximum moisture storage*

Location	Layer	Average thickness	Moisture content		Maximum moisture storage
			Maximum	Minimum	
		Inches	*Inches*	*Inches*	*Inches*
	L	0.71	0.041	0.002	0.039
Leverett	F	1.23	.253	.029	.224
	H	.51	.157	.033	.124
	Total	2.45	0.451	0.064	0.387
	L	.71	.041	.002	.039
Pelham	F	1.43	.295	.033	.262
	H	.56	.173	.036	.137
	Total	2.70	0.509	0.071	0.438
	L	1.00	.058	.003	.055
Southampton	F	1.42	.293	.033	.260
	H	.31	.096	.020	.076
	Total	2.73	0.447	0.056	0.391
	L	1.01	.059	.003	.056
Agawam	F	1.59	.328	.037	.291
	H	.45	.139	.029	.110
	Total	3 .05	0.526	0.069	0.457

Table 2.—*Daily drying rates of forest floor and soil*

Location	Interval	Drying rate per day	
		Forest floor	Soil
		Inches	*Inches*
	July 17-28, 1963	0.010	0.089
Leverett	Sept. 3-12, 1963	.012	.037
	April 16-May 12, 1964	.010	.057
	July 17-28, 1963	.020	.089
Pelham	Aug. 22-Sept. 12, 1963	.013	.050
	April 28-May 5, 1964	.018	.050
	April 28-May 12, 1964	.013	.069
Southampton	May 19-29, 1964	.012	.094
•	Mean	0.014	0.067

Table 4.—*Basic data, by plots*

Plot No.	Forest floor: Thickness L	Thickness F	Thickness H	Thickness Total	Forest floor: Weight per acre L	Weight per acre F	Weight per acre H	Weight per acre Total	Organic matter weight per acre L	Organic matter F	Organic matter H	Organic matter Total	Description: Geog. prov.[1]	Elevation	Soil group[2]	Drainage class[3]	Stand age	Basal area per acre	Site index
	In.	*In.*	*In.*	*In.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs*	*Lbs.*	*Lbs.*	*Lbs.*		*Ft.*			*Yrs.*	*Sq. Ft.*	*Ft.*
1-4	.5	1.0	.5	2.0	2,106	18,642	16,872	37,620	1,553	9,340	3,919	14,812	WU	1,250	CTT	4	70	192	59
1-5	.5	1.1	.4	2.0	3,620	22,353	17,436	43,409	2,645	14,931	3,885	21,461	WU	1,045	SG	5	37	226	66
1-6	.5	1.5	1.0	3.0	1,904	18,644	25,369	45,917	1,833	14,916	8,798	25,547	WU	1,020	SG	6	70	127	67
1-7	.3	.3	—	.6	3,495	7,472	—	10,967	3,337	3,764	—	7,101	WU	980	FFT	3	36	170	72
1-8	.5	1.0	—	1.5	3,231	15,310	—	18,541	3,129	10,293	—	13,423	WU	730	SG	5	39	194	62
1-9	.5	1.0	—	1.5	4,741	24,096	—	28,837	4,299	16,134	—	20,433	WU	735	FTO	4	39	225	71
2-1	.9	1.4	—	2.3	3,842	22,349	—	26,191	3,687	17,686	—	21,373	WU	470	FTT	4	50	222	77
2-2	.8	1.3	.5	2.6	3,426	27,690	13,541	44,657	3,366	25,959	5,509	34,834	EU	570	SG	5	75	223	61
2-3	.8	1.3	.3	2.4	3,148	35,094	12,574	50,816	2,729	13,166	2,502	18,397	WU	550	CTT	5	71	215	55
2-4	.8	1.1	.6	2.5	2,568	21,122	24,811	48,501	2,484	17,459	10,551	30,494	WU	800	FTO	4	71	242	80
2-5	.8	1.3	1.0	3.1	2,550	19,654	63,637	85,841	2,455	14,529	12,368	29,352	WU	860	SG	6	89	260	65
2-6	.5	1.0	.4	1.9	2,638	18,202	18,962	39,802	2,565	15,341	5,039	22,945	EU	620	SG	6	57	201	55
2-7	.5	1.1	.6	2.2	2,239	15,079	21,154	38,472	2,109	12,320	10,932	25,381	EU	650	SG	6	60	153	54
2-8	.6	1.0	.9	2.5	2,370	15,295	32,876	50,541	2,300	13,841	10,396	26,537	EU	560	SG	3	88	183	58
2-9	.8	1.1	.6	2.5	3,569	18,622	31,183	53,374	3,464	14,118	12,444	30,026	EU	570	SG	5	87	161	49
2-10	.5	1.0	.5	2.0	2,095	22,859	10,534	35,488	2,043	10,852	1,696	14,591	EU	1,020	FTT	3	41	196	60
2-11	.5	.7	.6	1.8	3,260	15,468	20,779	39,507	3,145	11,439	7,786	22,370	WU	450	FTT	2	41	164	68
2-13	.6	1.1	.6	2.3	2,098	18,497	15,193	35,738	1,971	14,246	5,252	21,469	EU	920	CTT	5	40	166	60
2-14	.4	.9	.6	1.9	1,653	16,903	13,923	32,479	1,597	14,052	6,747	22,396	EU	650	SG	3	51	164	51
2-15	.5	1.6	.4	2.5	1,678	28,226	8,122	38,026	1,608	25,386	4,654	31,648	EU	570	SG	2	68	248	66
2-17	1.1	1.0	.8	2.9	7,949	19,719	22,546	50,214	7,626	16,893	7,547	32,066	EU	1,050	SG	6	38	135	59
2-18	.6	2.1	—	2.7	2,622	34,616	—	37,238	2,555	28,269	—	30,824	CV	230	SG	5	43	143	65
2-19	1.3	1.3	.8	3.4	10,280	34,327	18,927	63,534	9,387	28,977	8,006	46,370	EU	1,000	FTT	5	65	187	56
2-21	.4	.6	—	1.0	1,694	8,477	—	10,171	1,567	4,468	—	6,035	EU	650	FTT	2	38	168	67
3-1	1.5	1.6	1.6	4.7	5,251	10,624	14,563	30,438	5,002	9,311	6,255	20,568	EU	660	FTT	3	48	206	65
3-2	.6	.9	1.1	2.6	4,515	15,077	9,760	29,352	4,347	13,345	6,755	24,447	WU	455	FTO	3	66	309	72
3-4	.9	.8	1.5	3.2	5,352	8,620	18,948	32,920	5,250	7,967	13,296	26,513	CV	240	SG	6	69	256	54
3-5	1.0	1.0	—	2.0	2,976	16,648	—	19,624	2,894	10,160	—	13,054	WU	1,440	FTT	1	34	151	72
3-6	1.1	1.1	1.5	3.7	4,781	13,185	20,596	38,562	4,637	12,386	15,113	32,136	EU	1,070	FTT	4	44	203	61
3-7	1.0	.6	.4	2.0	3,495	19,054	12,927	35,476	3,400	14,026	4,388	21,814	WU	1,025	FTT	5	44	240	55

3-8	1.1	.9	1.0	3.0	6,343	8,480	23,968	38,791	6,196	8,129	14,467	28,792	EU	980	FTT	3	49	205	57
4-1	.9	1.0	.4	2.3	3,570	15,840	42,649	62,059	3,476	12,070	8,118	23,664	EU	725	SG	5	41	214	67
4-2	1.0	1.1	.9	3.0	2,647	17,989	21,840	42,476	2,568	15,870	10,938	29,376	CV	220	FTO	4	38	168	61
4-3	1.0	1.0	.6	2.6	3,627	13,501	—	17,128	3,424	9,468	—	12,892	CV	200	FTO	4	62	259	73
4-4	.8	1.0	.3	2.1	5,095	14,226	10,573	29,894	4,924	12,744	3,162	20,830	CV	380	FTT	4	38	117	65
4-5	.8	1.4	.5	2.7	3,738	17,627	32,291	53,656	3,618	15,620	12,161	31,399	CV	220	FTO	4	42	145	60
4-6	.5	.6	—	1.1	2,741	11,709	—	14,450	2,662	6,434	—	9,096	WU	760	FTT	3	45	205	71
4-7	1.0	1.5	—	2.5	4,504	22,414	—	26,918	4,379	20,794	—	25,273	CV	200	(Peat)	0	46	176	56
4-8	1.0	1.0	.5	2.5	3,253	16,056	21,705	41,014	3,169	14,602	10,290	28,061	WU	1,090	FTT	4	48	217	61
4-9	1.0	1.6	.4	3.0	3,959	31,719	10,097	45,753	3,848	27,471	4,972	36,291	WU	1,160	FTT	4	72	191	55
5-1	.5	1.0	.5	2.0	1,777	22,149	10,660	34,586	1,726	20,845	8,890	31,461	EU	820	FTT	5	73	212	51
5-2	.5	1.3	.3	2.1	3,402	20,296	2,745	26,443	3,304	18,238	2,366	23,908	EU	860	SG	6	45	159	54
5-3	.5	1.0	.4	1.9	2,234	18,243	14,389	34,866	2,130	16,785	9,522	28,437	EU	950	SG	6	34	156	53
5-4	1.3	1.1	.5	2.9	10,021	18,010	13,188	41,219	9,714	15,227	6,125	31,066	EU	1,100	FTT	4	40	158	58
5-5	.6	1.3	—	1.9	3,644	12,751	—	16,395	3,311	8,078	—	11,389	EU	760	FTT	3	72	237	70
5-6	.5	1.0	—	1.5	1,828	19,323	—	21,151	1,605	11,620	—	13,225	EU	820	CTT	5	45	156	66
5-7	.6	1.5	.6	2.7	3,282	23,883	51,676	78,841	3,191	19,069	9,173	31,433	EU	400	SG	6	51	198	64
5-9	.5	2.0	—	2.5	2,983	28,329	—	31,312	2,883	18,387	—	21,270	EU	1,000	FTT	4	52	170	59
5-10	.5	1.6	.4	2.5	2,422	20,167	11,341	33,930	2,327	17,740	4,122	24,189	EU	575	FTO	4.5	57	202	61
5-11	.5	1.5	.5	2.5	4,417	24,721	17,029	46,167	4,232	21,038	9,279	34,549	EU	520	FTT	4.5	39	177	62
5-12	.5	1.0	—	1.5	2,829	19,654	—	22,483	2,835	14,443	—	17,278	EU	910	FTT	5	45	216	60
5-13	.5	2.0	.5	3.0	3,824	30,190	23,240	51,254	3,753	25,824	7,460	37,037	EU	605	FTO	4	55	241	61
5-16	.5	1.5	1.0	3.0	3,447	28,464	14,765	46,676	3,316	24,726	7,158	35,200	EU	730	SG	3	91	284	68
5-17	.5	1.5	.8	2.8	2,248	30,983	31,087	64,318	2,094	25,388	11,413	38,895	EU	770	FTT	4	91	213	64
6-1	.5	1.0	.5	2.0	3,692	17,738	21,560	42,990	3,613	15,700	5,146	24,459	EU	320	SG	6	54	223	58
6-2	.5	2.0	.5	3.0	2,606	18,443	14,919	35,968	2,508	16,971	10,736	30,215	EU	330	SG	6	52	194	58
6-3	.5	2.0	.5	3.0	3,765	33,074	26,452	63,291	3,593	27,807	8,121	39,521	EU	210	SG	6	62	172	47
6-4	.8	1.8	.5	3.1	4,127	19,119	30,785	54,031	4,010	15,193	9,664	28,867	EU	450	FTT	4	75	157	63
6-6	1.3	1.1	1.1	3.5	12,473	20,844	40,562	73,879	11,665	15,698	11,564	38,927	EU	210	SG	6	65	143	56
6-7	.6	1.8	.8	3.2	3,381	17,983	26,907	48,271	3,075	13,216	18,459	34,750	EU	206	SG	0	39	92	57
6-11	.5	2.0	.5	3.0	2,335	32,980	29,154	64,469	2,231	19,858	10,626	32,715	EU	295	SG	6	96	136	56
7-4	.5	1.8	.5	2.8	5,402	25,240	30,274	60,916	5,210	16,475	6,462	28,147	CP	90	SG	6	43	200	54
7-6	.5	1.8	.3	2.6	2,643	20,301	8,586	31,530	2,560	16,267	3,462	22,289	CP	25	FTO	4	47	201	60
7-11	.5	1.8	.5	2.8	4,102	30,835	19,948	54,885	3,973	26,217	6,669	36,859	CP	100	SG	5	55	160	52
10-6	.5	.9	.6	2.0	3,358	26,781	24,901	55,040	3,198	20,832	11,832	35,862	CP	40	FTO	2	36	165	70

[1]Geographical province. WU = Western Upland, CV = Connecticut Valley, EU = Eastern Upland, CP = Coastal Plain.
[2]Soil group: SG = sands and gravels, CTT = coarser textured till, FTO = fine-textured outwash, FTT = fine-textured till.
[3]Drainage class: 0 = very poorly drained, 1 = poorly drained, 2 = somewhat poorly drained, 3 = moderately well drained, 4 = well drained, 5 = somewhat excessively drained, 6 = excessively drained.

Table 5.—*Standard deviations, standard errors of the mean, and coefficients of variations for forest-floor and organic matter weights, and moisture contents of samples, at Leverett (LEV) and Agawam (AG), Massachusetts*

Location	Variable	Number of observations	Mean	Standard deviation	Coefficient of variation, percent	Standard error* 24 or 32 sample mean	Standard error** 4 sample mean	$T_{.05}$ confidence limits as percent of mean: 24 or 32 sample mean	4 sample mean
				FOREST FLOOR *Pounds per acre*					
LEV	L	24	7,394	1,885	26	375	942	10.0	40
LEV	F	24	24,809	5,109	21	1,043	2,554	8.7	33
LEV	H	24	23,330	6,340	27	1,290	3,170	11.0	35
LEV	L,F,H	24	55,533	9,740	18	1,990	4,870	7.4	28
AG	L	32	5,000	1,126	22	199	563	8.1	36
AG	F	32	18,116	3,057	17	540	1,528	6.1	27
AG	H	32	24,917	10,306	41	1,822	5,153	15	66
AG	L,F,H	32	48,037	10,580	22	1,870	5,290	7.9	35
				ORGANIC MATTER *Pounds per acre*					
LEV	L	24	6,877	1,758	26	359	879	11.0	41
LEV	F	24	20,197	6,350	31	1,296	3,175	13.0	50
LEV	H	24	8,547	3,523	41	719	1,762	17.0	66
LEV	L,F,H	24	35,620	8,612	24	1,758	4,306	10.0	38
				ORGANIC MATTER *Percent*					
LEV	L	24	92.96	2.12	2.3	0.4	1.1	1.0	4
LEV	F	24	80.95	5.63	7.0	1.2	2.8	3.0	11
LEV	H	24	37.25	9.32	25.0	1.9	4.7	11.0	40
				FOREST FLOOR *Moisture percentage*					
LEV May 29, 1964	L	4	19.8	5.7	22	1.2	2.8	12	45
LEV May 29, 1964	F	4	38.6	13.5	36	2.7	6.7	15	55
LEV May 29, 1964	H	4	34.7	8.7	25	1.8	4.3	10	40

LEV May 29, 1964	L	4	13.2	3.2	24	0.7	1.6	10	39
LEV May 29, 1964	F	4	84.8	28.7	34	5.9	14.4	14	54
LEV May 29, 1964	H	4	46.9	9.9	21	2.0	5.0	12	44
LEV April 16, 1964	L	4	126.2	13.1	10	2.7	6.6	4.4	16
LEV April 16, 1964	F	4	219.5	33.3	15	6.8	16.7	6.4	24
LEV April 16, 1964	H	4	93.6	11.4	12	2.3	5.7	5.2	19
LEV April 9, 1964	L	4	145.0	8.7	6.0	1.8	4.4	2.6	9.6
LEV April 9, 1964	F	4	240.3	38.8	16	7.9	19	6.8	26
LEV April 9, 1964	H	4	102.9	33.7	33	6.9	17	13.8	52
			FOREST FLOOR *Moisture content, inches*						
LEV May 29, 1964	L	4	0.0065	0.0034	53	0.0007	0.0017	22	83
LEV May 29, 1964	F	4	.0417	.0176	42	.0036	.0088	17	67
LEV May 29, 1964	H	4	.0454	.0102	23	.0021	.0051	9.5	36
LEV May 29, 1964	L,F,H	4	.0935	.0193	21	.0039	.0096	8.7	33
LEV May 19, 1964	L	4	.0039	.0013	32	.0002	.0006	13	49
LEV May 19, 1964	F	4	.0892	.0436	47	.0089	.0218	21	78
LEV May 19, 1964	H	4	.0484	.0195	40	.0040	.0097	17	64
LEV May 19, 1964	L,F,H	4	.1414	.0573	40	.0117	.0287	17	64
LEV April 16, 1964	L	4	.0378	.0089	24	.0018	.0045	10	38
LEV April 16, 1964	F	4	.2172	.1014	47	.0207	.0507	20	74
LEV April 16, 1964	H	4	.0715	.0155	22	.0031	.0077	9.1	34
LEV April 16, 1964	L,F,H	4	.3265	.0961	29	.0196	.0481	12	47
LEV April 9, 1964	L	4	.0480	.0134	28	.0027	.0067	12	44
LEV April 9, 1964	F	4	.2671	.1471	55	.0300	.0736	23	88
LEV April 9, 1964	H	4	.1284	.0655	51	.0134	.0328	22	81
LEV April 9, 1964	L,F,H	4	.4447	.2120	48	.0433	.1060	20	76

Notes: $T_{.05}$ for 3 d.f. — 3.18, $T_{.05}$ for 23 d.f. — 2.07, $T_{.05}$ for 31 d.f. — 2.04.

*Standard errors are estimated at N=24 for variable with four observations, are actual values for variables with 24 and 32 observations.

**Standard errors for four-sample means are estimates for variables with 24 and 32 observations These errors are actual values for variables with four observations.

L,F,H=Litter, fermentation, and humidification layers of the forest floor.

Table 6.—*Forest floor thicknesses and weights in New England, New York, Pennsylvania, and Minnesota*

Location	Portion of forest floor measured	Forest floor: Thickness	Forest floor: Oven-dry weight	Age of stand	Reference
		Inches	*Pounds*	*Years*	
Connecticut River watershed	F,H	2.4	—	70	Morey 1942
Pennsylvania	F,H	1.3 to 4.3	—	virgin	Lull 1959
New Hampshire	F,H	1.4 and 2.3		stands	
Massachusetts	L	0.6	—	about	Cline and
	F	0.8	—	50 yrs.	Spurr 1942
	H	0.7	—		
New Hampshire	L,F,H	—	93,158	100	Lunt 1932
Connecticut	L,F,H	—	21,590	27	
	L	—	2,875		
Syracuse, N. Y.	F	—	9,232	18	
	H	—	12,108		Day 1940
	L	—	2,333		
Phoenix, N. Y.	F	—	14,029	31	
	H	—	16,262		
	L	—	3,476		Alway, Methley,
Minnesota	F	—	24,970	250	and Younge
	H	—	40,910		1933

Table 7.—*Thickness, oven-dry weight, and organic matter content of forest floor layers by geographical provinces and soil parent material groups*

Horizon	Overall average and standard deviation	Average and standard deviation by geographical province				Average and standard deviation by soil parent material groups			
		Western Upland	Connecticut Valley	Eastern Upland	Coastal Plain	Sands and gravel	Aeolian or fine-textured outwash	Coarse-textured till	Fine-textured till
	THICKNESS OF FOREST FLOOR *Inches*								
L	0.69±0.26	0.69±0.23	0.87±0.15	0.68±0.30	0.50±0.00	0.63±0.22	0.67±0.21	0.60±0.14	0.79±0.34
F	1.25±0.40	1.02±0.34	1.27±0.44	1.33±0.39	1.58±0.45	1.36±0.40	1.28±0.40	1.10±0.14	1.13±0.42
H	0.52±0.38	0.40±0.38	0.54±0.53	0.57±0.36	0.48±0.13	0.60±0.33	0.55±0.30	.0.35±0.27	0.45±0.46
Total	2.46±0.67	2.11±0.68	2.69±0.35	2.57±0.69	2.55±0.38	2.59±0.51	2.50±0.45	2.05±0.40	2.37±0.92
	FOREST FLOOR WEIGHT *Hundreds of pounds per Acre*								
L	37± 20	33± 8	39± 11	40± 25	39± 12	37± 22	34± 8	23± 6	41± 22
F	205± 68	194± 67	184± 83	208± 66	258± 44	215± 64	207± 52	229± 82	186± 77
H	169±133	139±159	119±128	191±123	209± 92	232±144	157±112	112± 76	116±103
Total	410±158	366±177	343±117	437±154	506±130	483±156	392±129	363±121	344±150
	ORGANIC MATTER WEIGHT *Hundreds of pounds per Acre*								
L	35± 19	29± 8	38± 10	37± 23	38± 11	35± 20	33± 7	20± 5	39± 21
F	160± 58	135± 52	158± 70	167± 57	200± 47	174± 54	169± 43	121± 44	144± 69
H	65± 47	45± 43	57± 62	74± 44	71± 34	81± 41	67± 47	29± 23	53± 50
Total	260± 85	210± 78	253± 66	279± 83	308± 69	290± 58	269± 74	170± 37	236±106

Table 8.—*Correlation of thickness and weight of the total forest floor and its layers with stand age, basal area, site index, drainage class, and elevation*

Item	Age	Basal area	Site index	Drainage class	Elevation
			DEPTH		
Total floor	0.334**	0.012	−0.242	0.136	−0.203
L	−0.014	0.011	−0.017	0.012	0.146
F	0.261*	−0.137	−0.225	0.111	−0.367*
H	0.311	0.116	−0.212	0.094	−0.049
			WEIGHT		
Total floor	0.417**	−0.068	−0.306**	0.374**	−0.218
L	−0.090	0.097	−0.139	0.104	0.020
F	0.109	−0.011	−0.226	0.192	−0.158
H	0.355**	−0.052	−0.221	0.298*	−0.188
			WEIGHT		
Total organic content	0.313**	−0.083	−0.391**	0.226	−0.261*
L	−0.090	−0.100	−0.144	0.117	−0.036
F	0.290*	0.015	−0.256*	0.201	−0.212
H	0.117	−0.244*	−0.231	0.019	−0.171

Table 9.—*Observed moisture content, in percent, by layers*

By weight						By volume					
Maximum			Minimum			Maximum			Minimum		
L	F	H	L	F	H	L	F	H	L	F	H
LEVERETT											
254.4	317.5	163.5	10.2	36.0	37.8	7.30	20.7	34.6	0.24	2.54	7.96
171.4	272.4	155.5	12.9	30.8	32.0	7.18	18.8	35.4	.34	2.60	7.73
170.8	259.2	153.3	14.8	41.1	28.4	6.78	18.6	29.2	.30	2.42	4.68
164.9	246.4	148.6	14.0	43.7	26.8	6.06	17.3	27.2	.24	2.20	6.78
PELHAM											
163.7	294.5	237.0	9.7	15.2	15.2	8.32	33.2	39.6	0.22	1.20	4.00
159.5	273.9	176.9	8.9	23.7	23.4	7.12	32.2	34.5	.24	1.22	4.90
158.2	257.0	179.3	10.4	22.0	29.9	7.49	19.1	30.9	.23	1.89	6.31
153.8	250.2	168.0	10.9	22.7	29.3	6.33	25.2	28.4	.27	2.84	6.40
SOUTHAMPTON											
291.3	247.2	137.5	5.2	24.2	16.0	4.76	21.1	34.1	0.15	2.06	4.22
149.4	235.1	118.4	6.2	25.8	16.3	4.54	18.5	29.3	.17	2.10	5.47
123.9	232.3	108.8	7.2	29.8	31.8	4.34	18.2	27.4	.20	2.76	7.07
123.6	222.3	105.5	8.0	31.1	32.0	4.03	16.0	27.3	.25	3.03	9.80
AGAWAM											
150.5	296.6	138.7	8.4	26.8	31.0	4.66	24.4	38.6	0.25	1.64	5.61
149.6	253.8	117.0	8.8	32.6	24.8	4.59	17.6	29.0	.28	2.22	6.98
147.8	235.3	105.9	7.9	37.2	38.3	4.70	15.2	26.8	.30	2.89	7.70
—	233.3	—	8.3	—	37.3	4.40	14.3	24.9	.31	3.52	8.40
AVERAGE VALUES FOR ALL PLOTS											
168.9	257.9	147.7	9.5	29.5	28.1	5.79	20.6	30.8	0.25	2.32	6.50