Station Paper 47

April 1952

A Method of Measuring

Increase in Soil Depth And Water-Storage Capacity

Due to Forest Management

by

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CONTENTS

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INTRODUCTION

Conservationists, engineers, and others who deal with water problems have become more and more concerned in recent years with increasing the storage of water in the ground. Their concern has centered around problems of flood control and storage of water for later use by plants or animals, including man.

By reason of their location in steep headwaters regions, forest soils are of particular importance in flood control; they are our natural reservoirs.

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Methods of increasing the water-storage capacity of the soil by modifying its structure have been studied by numerous investigators. Early studies were more concerned with agricultural soils, but in recent years a considerable interest has grown in methods of increasing the storage capacity of forest soils. A limiting factor in the improvement of the storage capacity of these soils is that many of them are shallow to bedrock or impervious hardpan. Because of this, it has generally been thought that their storage capacity is restricted by their depth.

However, studies made by the Northeastern Forest Experiment Station indicate that, by using proper forest-management practices, man can increase the depth and thus the water-storage capacity of shallow forest soils. This article offers data to show, in a limited way, how forest management accomplishes this, and presents a method of measuring these changes in soil depth.

HOW MANAGEMENT IMPROVES THE SOIL

A soil is made up of solid particles, both mineral and organic, and pore spaces that are filled with water and air. Mineral soil is formed from rock, a slow process. It may take a thousand years to form one inch of soil. Organic matter, which comes from plants and animals, forms at a much faster rate.

The volume of the soil, and thus its depth, is increased by adding to either the solid portion or the pore space.

Vegetation builds up the humus (organic content) and increases the pore space (2, 3, 4). Foresters who have studied the forest floor in rocky areas know that individual rocks are often covered with pure organic matter. In places where the land was used for pasture or crops before the present forest stand formed--or where fire had destroyed the forest floor--it is obvious that the humus was formed during the life span of the timber stand that now occupies the site. In New England you can find spruce stands growing on rock ledges where there is humus, but no mineral soil. This humus indicates that organic matter accumulates much faster than mineral soil forms.

Kellogg (1) recognized the possibility of changing soil depth through management. "Frequently," he wrote, "there is a marked difference in volume weight as a result of cultivation, the thickness of the A-horizon is reduced without any loss of soil." (By "soil" Kellogg means mineral soil.) In this case, cultivation resulted in a loss of pore space and organic-matter content.

The forest soils most capable of storing water are found under well-stocked mature stands. Studies in the Northeast (2, 3, 4) have shown that well-stocked mature forests have a deeper humus layer than understocked young stands. They have shown also that grazed forest lands have less humus depth than ungrazed forests, the magnitude of the difference varying with the intensity of grazing.

From these studies we have concluded that management to produce well-stocked stands increases humus depth. Proper management at the same time prevents the kind of abuses--such as fire, grazing, and overcutting--that damage or destroy humus.

MEASURING THE EFFECT OF MANAGEMENT

Methods developed by the Northeastern Forest Experiment Station in flood-control surveys were used to determine to what extent the depth of shallow forest soil can be increased by management, and how this increase in depth affects the water-storage capacity of the soil. Under these methods, pore space and organic content are measured and compared as criteria of change in soil depth.

Certain forest stands were selected to represent different stand ages, stocking, and present and past treatments, that is, management or lack of management. Two types of field measurements were made in collecting the necessary data. First, information was taken on depth of humus under these various stand conditions.

Next, quantitative measurements were made in each major horizon of these forest soils to obtain horizon depth, organic-matter content, retention-storage capacity, and detention-storage capacity. In this discussion we will deal only with measurements of medium-texture (from very fine sandy loams to silt loams inclusive), shallow (no deeper than 18 inches to bedrock), and well-drained (no mottling or other evidence of impeded drainage) soils.

As examples of how management can change soil depth, we have taken three stand (mixed hardwoods) conditions. In the soils under these stand conditions, pore space and organic-matter content were compared in the top 6.5 inches of the profile. In making these comparisons it was necessary to consider equal depths of soil; the depth of 6.5 inches was that below which there were no differences among the soil conditions studied.

The top 6.5 inches of soil under the first stand condition contained 3.5 inches of humus and 3.0 inches of A_2. The second soil contained 2.3 inches of humus, 3.0 inches of A_2, and 1.2 inches of subsoil. The third contained 2.0 inches of humus, 3.0 inches of A_2, and 1.5 inches of subsoil.

The three stand conditions, and the soils under them, can be summarized as follows:

1. <u>Well-stocked, 80-year-old, ungrazed stands--shallow, silt-loam soil</u>.

Humus: Mull 3.5 inches deep; organic content 37.0 percent by volume; retention storage 41.1 percent by volume; detention storage 23.4 percent by volume.

A_2 horizon: 3.0 inches[2] deep; organic content 11.5 percent; retention storage 36.8 percent; detention storage 14.8 percent.

Subsoil (mineral soil between the A_2 and bedrock): Organic content 4.5 percent; reten-

[2] THIS IS NOT A MATHEMATICAL AVERAGE FOR THE AREA; IT IS AN APPROXIMATION. A_2 DEPTHS VARIED BY SOIL SERIES AND OTHER CONDITIONS, AND GOOD AVERAGE FIGURES ARE NOT AVAILABLE. HOWEVER, A CORRELATION STUDY MADE TO DETERMINE IF THERE WAS A RELATIONSHIP BETWEEN HUMUS DEPTH AND A_2 DEPTH INDICATED THAT A_2 DEPTH WAS PROBABLY INDEPENDENT OF HUMUS DEPTH FOR THE AREA STUDIED. A STUDY TO DETERMINE IF A RELATIONSHIP EXISTED BETWEEN A_2 DEPTHS IN GRAZED AND UNGRAZED STANDS ALSO GAVE NEGATIVE RESULTS.

tion storage 36.3 percent; detention storage 10.6 percent.

2. Understocked, 30-year-old ungrazed stands--shallow, silt-loam soil.

Humus: Mull, 2.3 inches deep; organic content 37.0 percent; retention storage 41.1 percent; detention storage 23.4 percent.

A_2 horizon: 3.0 inches[2] deep; organic content 11.5 percent; retention storage 36.8 percent; detention storage 14.8 percent.

Subsoil: Same as the 80-year-old stand in organic content and storage capacity.

3. Average all-aged, grazed stands--shallow, silt-loam soil.

Humus: Mull, 2.0 inches[3] deep; organic content 26.9 percent; retention storage 41.4 percent; detention storage 12.6 percent.

A_2 horizon: 3.0 inches[2] deep; organic content 10.4 percent; retention storage 38.3 percent; detention storage 13.7 percent.

Subsoil: Same as the 80-year-old stand in organic content and storage capacity.

From these data, pore space and organic content were determined for each soil as follows (the first soil is used as an example):

The humus has a total pore space of 64.5 percent (41.1 percent retention plus 23.4 percent detention). Subtracting from 100 percent leaves a solid volume of 35.5 percent. Humus depth of 3.5 inches x 35.5 percent = 1.24 inches depth of solid material: 1.24 inches x 37 percent organic-matter content = 0.459 inch depth of organic matter. Depth of detention pore space is determined by multiplying 23.4 percent detention pore space by 3.5 inches of humus = 0.819 inch. Depth of retention pore space is 41.1 percent x 3.5 inches = 1.438 inches.

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[3] THIS IS ALSO AN APPROXIMATION, BASED ON A LIMITED NUMBER OF OBSERVATIONS. IN SOME WATERSHEDS IN THE NORTHEAST WHERE COMPARISONS WERE MADE BETWEEN AVERAGE HUMUS DEPTHS UNDER GRAZED AND UNGRAZED STANDS THE DIFFERENCES WERE CONSIDERABLY GREATER THAN THOSE SHOWN BY THIS STUDY.

The A_2 horizon has a solid portion of 48.4 percent, which when multiplied by 3.0 inches depth = 1.45 inches. Organic-matter content is 1.45 inches x 11.5 percent = 0.167 inch. Depth of detention pore space is 14.8 percent x 3.0 inches = 0.444 inch. Depth of retention pore space is 36.8 percent x 3.0 inches = 1.104 inches.

Using this procedure, similar computations were made for all three soils. These are shown in table 1.

Table 1.--Comparison of organic-matter content and pore space in soils under three forest-stand conditions

1. WELL-STOCKED MATURE STANDS

Horizon	Organic-matter content	Pore space			Organic matter plus pore space
		Detention	Retention	Total	
	Inches	Inches	Inches	Inches	Inches
Humus	0.459	0.819	1.438	--	--
A_2	.167	.444	1.104	--	--
Total	0.626	1.263	2.542	3.805	4.431
2. UNDERSTOCKED YOUNG STANDS					
Humus	0.302	0.538	0.945	--	--
A_2	.167	.444	1.104	--	--
Subsoil	.029	.127	.436	--	--
Total	0.498	1.109	2.485	3.594	4.092
3. AVERAGE ALL-AGED GRAZED STANDS					
Humus	0.247	0.252	0.828	--	--
A_2	.150	.411	1.149	--	--
Subsoil	.036	.159	.544	--	--
Total	0.433	0.822	2.521	3.343	3.776

The relative differences in total depths of the three soils are equal to the differences between totals of organic-matter content and pore space of the upper 6.5 inches. The volume of mineral soil remains the same regardless of treatment (assuming no accelerated erosion.) Thus the well-stocked older stand has a soil that is 0.339 inch deeper than the young understocked stand and 0.655 inch deeper than the grazed stand.

This method gives a conservative indication of the changes in soil depth that can be brought about through forest management. A method using bedrock as a reference point would give an exact and slightly greater change. However, the variability of the depth of mineral soil above bedrock precludes such a procedure except for long-term experiments.

Increasing the depth of shallow forest soils increases their storage capacities. To show the approximate difference in storage capacities of shallow forest soils under various conditions of cover, it is necessary only to compare the differences in pore space as shown in table 1.

If all pore space is utilized, the soil under the well-stocked stand will hold at saturation 0.211 inch more water than the soil under the young understocked stand and 0.462 inch more than the soil under the grazed stand. At field capacity the first soil will hold 0.057 inch more water than the second and 0.021 inch more than the third.

The examples shown are for average conditions found in the Allegheny River watershed. They are illustrative rather than all-inclusive. Much more extreme examples could be taken from areas where fire or grazing has almost or completely destroyed the humus and has brought about greater loss of organic matter and increased compaction in the A_2 and even in the upper B horizon. Here the differences in soil depth and water-holding capacity between the abused areas and the undisturbed or well-managed forest areas could be several times the average differences shown by the examples.

S U M M A R Y

Past studies of forest soils, made in connection with flood-control surveys in the Northeast, indicate that the depth and water-storage capacity of shallow forest soils can be increased through the use of forest-management that will maintain well-stocked stands.

The effect of management on the depth of forest soils was measured by determining organic-matter content and pore space of soils found under different forest-stand conditions. The various forest-stand conditions were used as criteria of forest management or lack of it.

Although the study was rather limited in scope (the effects of forest-management measures such as cultural operations, cutting practices, and so on, were not considered), the differences in humus and pore space under well-stocked mature stands, understocked young stands, and grazed all-aged stands show how the effects of management can be measured.

The method could also be used to determine actual effects of management on the soil under a particular forest stand over a long period.

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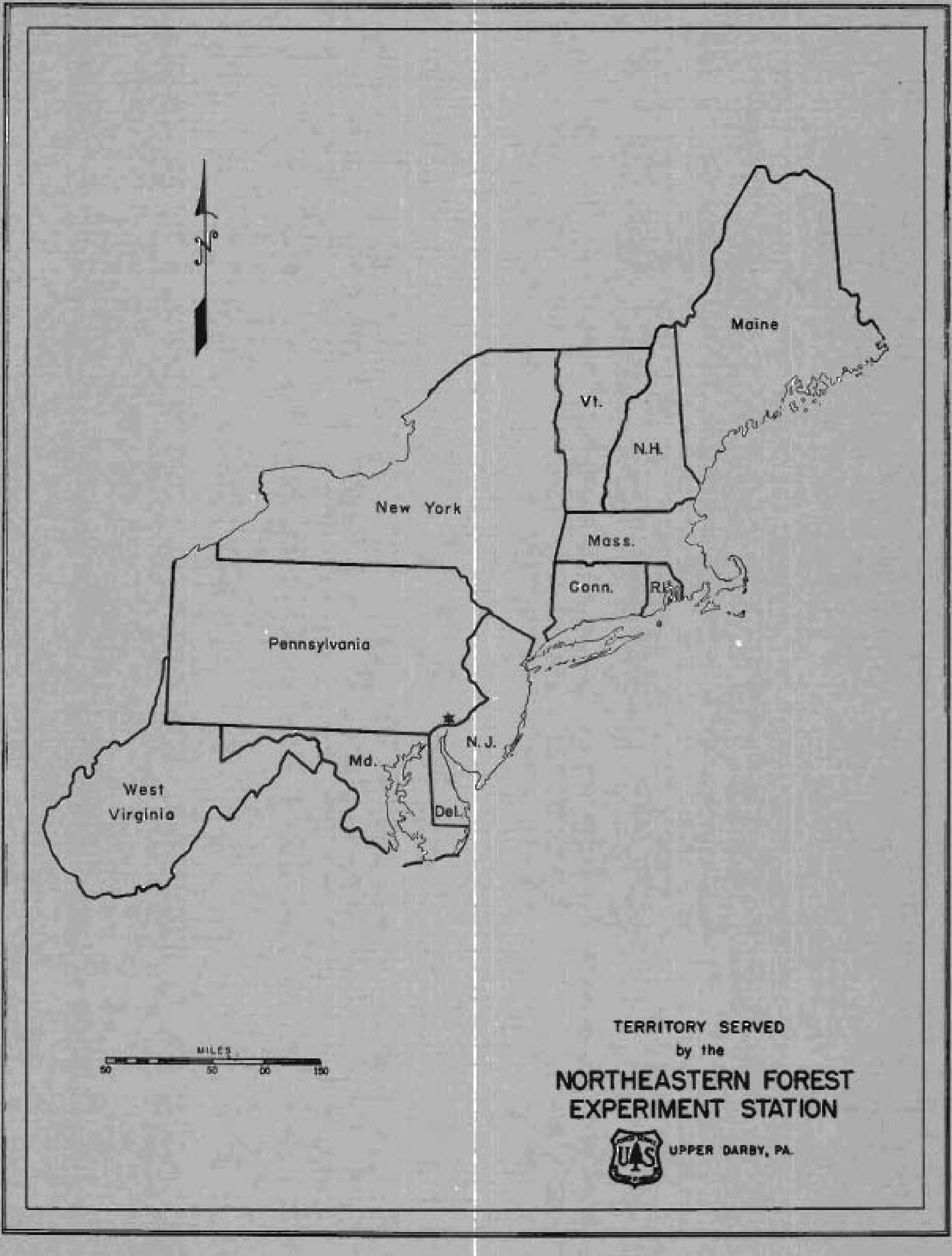
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