Litter Keeps Forest Soil Productive

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MILLIONS each year for fertilizers! That is the heavy expenditure by American farmers to keep agricultural soils productive. Forests, no less than corn and cotton, must rob the soil of nutrient material for their nourishment, and this material must be replenished. The farmer can conform his bought-and-paid-for fertilizers to the needs of his particular crops; but with timber, soil maintenance brings up a special set of questions. Do cutting systems and logging methods affect the soil? What is the effect of forest fires on the soil? Will it pay to hold forest lands for timber crops, and, if so, what kind of forest lands? The answer to such questions as these must be found, in whole or in part, in the characteristics and requirements of forest soil fertility.

Forest Soil Characteristics

The characteristics of a productive agricultural or forest soil are difficult to define. Broadly speaking, a productive soil is obviously one that favors vegetative growth. This growth depends upon a favorable condition of physical structure and chemical constitution of the soil, and these are closely related to certain essential biologic factors. Consequently, to maintain a fertile soil it is imperative to maintain these several factors—favorable physical structure, favorable chemical constitution, and favorable biological activity. Interference with any one of these interrelated factors may express itself unfavorably upon soil productiveness.

The large amount of surface litter on the floor of the forest and the abundant organic material derived from it are the most obvious characteristics that distinguish fertile forest soils from agricultural soils. The forest builds up and fertilizes its own soil. The presence of forests on rocky areas, where the mineral soil would be totally insufficient to support any paying agricultural crop is a powerful indication of the importance to tree growth of organic material.

Another difference between forest and agricultural soils is the distinctness of soil layers in the forest. The surface of a forest soil is covered with loose litter and detritus. On decomposition this material gives rise to another purely organic layer that is partially decayed, more or less compacted, and bound together by fine roots and fungous mycelium. This decayed organic layer mixes with the mineral soil from beneath to give rise to still another fairly definite soil layer. The underlying mineral soil itself may contain very little or no organic material. Below the mineral soil is found the country rock in various stages of disintegration. In agricultural soils, due to continued plowing and cultivation, distinct layers are not so conspicuous, although the same gradation downward from loose litter to mineral soil is commonly present.

Litter Maintains Fertility

It has been estimated that four-fifths of the nutrients assimilated each year by forest trees are returned to the soil in the form of leaves and detritus. These nutrients, however, will not become available until the returned organic material has been altered by decomposition. The time required for adequate decomposition varies from one to many years. For the average of Southern hardwood forest conditions a period of two or three years is probably sufficient. Considering the fact that such a large percentage of the nutrients assimilated by forest trees is returned to the soil, it is obvious that forest soils are more economical than cultivated soils. Particularly is this true in the nitrogen economy. It is believed that forests add to the soil more nitrogen than they remove. This is true only when biological activities in the soil are favored and there is an annual return of organic matter in the form of leaf litter or otherwise.

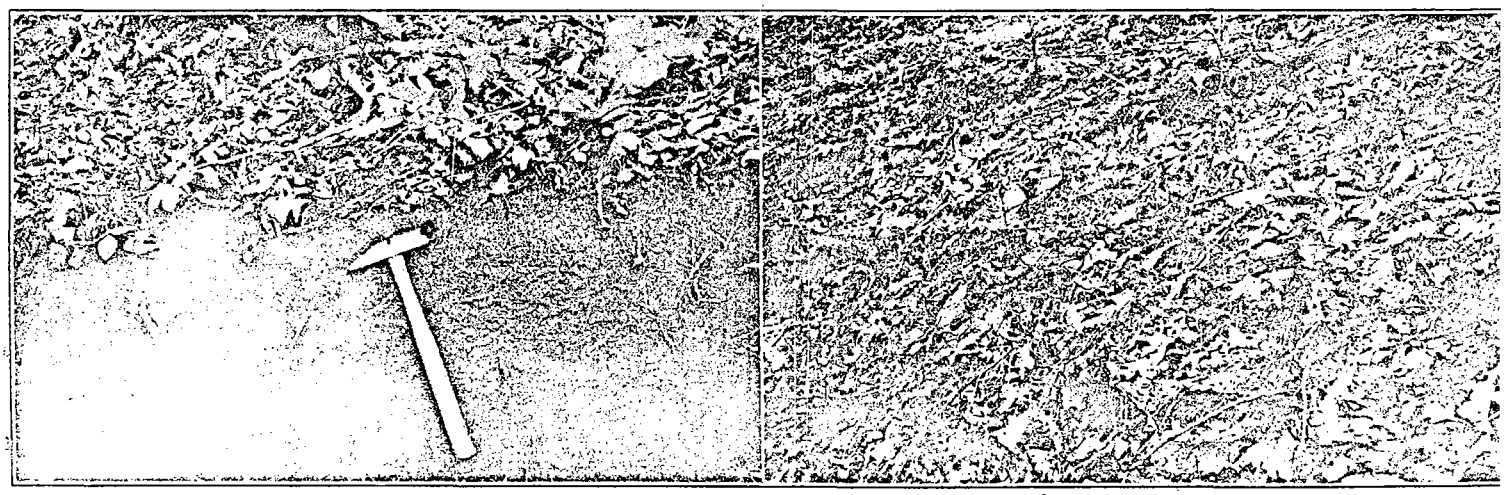
The carpet of leaves, twigs, bark, etc. has marked influence upon the condition of the soil underneath. Water content and temperature of the soil are particularly affected. Litter not only serves to absorb and retain moisture, it also tends to prevent too rapid transpiration from below and this serves to retard the drying of the surface soil.

The protective influence of forest litter against washing away of the mineral soil is one of much significance throughout the Southern hardwood region. Particularly is this true where rainfall is abundant and the topography irregular, for under these conditions gullying and washing become a serious menace.

Within the soil itself, decayed litter has an ameliorating effect upon the soil structure. When mixed with sandy soil, organic matter tends to increase water holding capacity and to bind the soil particles together. In a heavy clay region organic material renders the soil more friable, more permeable, better aerated and consequently more favorable to plant growth.

Biological Activity Imperative

The forest litter is particularly important in its relation to complex biological activities essential to soil fertility. It is largely through the activity of fungi, bacteria, nematodes, and other forms of microscopic life that certain essential nutrients, principally nitrates, are rendered available to plants. These organisms are fostered and favored by the forest litter upon which they live and derive the energy for their existence. Myriads of these microscopic plants and animals spend their lives of incessant activity changing forest litter into humus, reducing complex organic materials to simpler substances. The significance of micro-organisms to timber production is illustrated by the equilibrium of biological factors in our highest yield



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Left—Litter protects and nourishes the feeding roots that lie immediately beneath. Right—Nature's carpet retains moisture, prevents erosion and supplies nutrients to the plant roots.

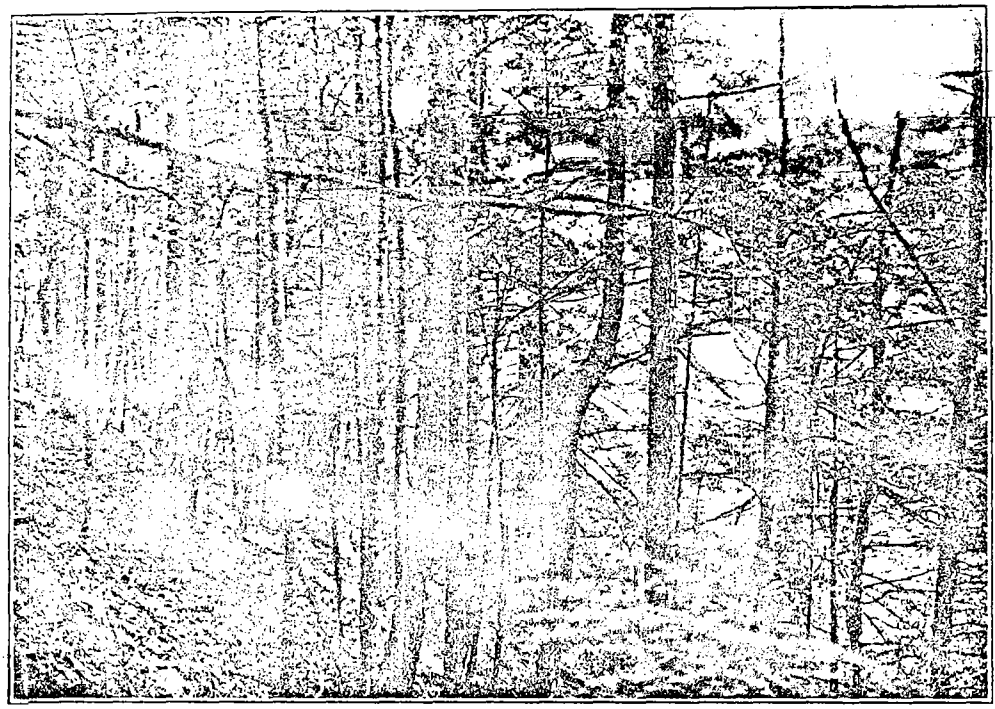

Photo by U. S. Forest Service.

Even stony slopes well protected by litter are a money-making proposition.

ing virgin hardwood forests. Here, living together in the upper layers of the forest floor, exists an abundant flora and fauna composed of fungi, bacteria, nematodes, insects, worms. This society of organisms, when supplied with organic material as a source of energy, is largely responsible for the high fertility of virgin forest soil. When cutting disrupts the forest floor, and subsequent management entirely changes the equilibrium of virgin conditions, then this great society of organisms is destroyed and the individual groups must either adjust themselves to a new environment or disappear. This change in most cases retards nitrification, and the availability of plant nutrients decreases at once.

Under optimum conditions for biologic activity, the forest litter is readily changed to humus and sufficient organic nitrogen is reduced to nitrates to supply the demands of the crop. Unfavorable conditions interfere with this process, resulting in an accumulation of layers of more or less undecomposed organic material, often called raw humus. Under these circumstances nitrification proceeds slowly and growth is retarded. Drying of the forest floor and low temperatures appear to encourage the development of raw humus, but not all the factors of its production are well understood. The practice in northern Europe of avoiding pure stands of conifers by mixing beech and birch in the conifer plantations is based on considerations of forest litter and nitrification. Decomposition of the litter under a pure conifer stand is slow and incomplete. This difficulty seems to be remedied by additions of beech and birch litter.

Thus is it agreed that by proper forest management, nitrate formation may be accelerated, resulting in increased timber production, and consequently greater profit to the timberland owner. Desirable practice to favor nitrate formation will depend upon the existing forest floor, nature of the stocking, and many other factors that can be determined only by a thorough investigation of representative forest areas.

Following observations both in the United States and in Europe that cutting practices may influence soil conditions, the Appalachian Forest Experiment Station has undertaken to determine the principal factors of forest soil fertility in the Southern Appalachian region. A preliminary study of the subject has brought out the fact that management for the improvement of the forest floor, together with complete control of forest fires, is essential to soil fertility. Field observation offers abundant evidence that litter conditions have received insufficient consideration at the hands of practical foresters, that these conditions may be profoundly influenced, for better or for worse, by the methods followed in logging and slash disposal and by fires. The changes so made in the forest will subsequently be expressed in accelerated or retarded growth.

Cutting Changes Soil Conditions

Cutting disturbs the forest floor equilibrium chiefly by changing the conditions of light, temperature, and moisture. In the hardwood region of the southern United States the temperature in the forest is relatively high, precipitation is ample and, as a result, decomposition of the litter is rapid. Here a favorable balance of biological activities generally exists, providing that there is no interference with the annual return of the leaf litter. After heavy or clear cutting, however, the forest floor soon dries out and microbiological activities undergo profound changes. But the most extreme loss to soil fertility is sustained when the litter is destroyed by fire.

Timberland Owners Pay for Fires

Forest fires that destroy the litter on the forest floor not only remove the source of essential organic material, but also bring about disastrous changes in the biologic activities in the soil. It may require many years for the soil to return to its former condition. Appraisal of fire damage has, for the most part, concerned itself with physical damage to standing timber and reproduction. The damage of fires to forest soils must be a matter of considerable significance, but there are no data available at present from which one may estimate this damage on an economic basis.

The annual return of leaf litter in a well-forested hardwood area may be considered as approximately two tons per acre. From the best data available on this subject this amount of hardwood litter contains 25 to 35 pounds of nitrogen, 12 to 15 pounds of phosphoric acid, and 5 to 7 pounds of potash. This, then, may be considered to represent the equivalent fertilizer value of the annual leaf fall on one acre of hardwood forest. It would have a cash value on the market of approximately five to eight dollars. Under normal forest conditions, these nutritive elements will be slowly supplied through decomposition of the litter, so that they may be efficiently utilized by the growing plant roots. When the litter is burned its mineral content will be left behind in the form of ash,

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Photos by U. S. Forest Service

which, however, may soon be dissipated through leeching and washing. The destruction of litter through fires is a decided loss to the land owner. The aggregate depletion of soil fertility thus brought about, if computed in dollars and cents, would undoubtedly reach a stupendous figure.

Studies are under way by the Appalachian Forest Experiment Station designed to furnish a scientific basis for determining the damage to the forest soil from fires. As a part of this study, litter conditions on the hardwood forest floor of the Southern Appalachian mountains have been compared and data from this comparison may be used to illustrate the importance of litter to forest soils. The following statistics represent average litter conditions in the fall of 1928, just prior to the leaf fall:

Location	Pounds of Dry Litter Per Acre	Equivalent Precipitation Absorbed, Expressed in Inches
Middle and upper slope, North aspect	10,212	0.241
Middle and upper slope, South aspect	3,146	0.033
Lower slope, North aspect	13,310	0.186
Lower slope, South aspect	16,359	0.190
Cove	9,148	0.214

The above data illustrate the meager amount of litter present in the drier south slope forests, so extensive in the Southern Appalachian mountains. This condition is largely due to the influence of fire and topographic position. The exposure to greater heat of the sun increases transpiration on the south slopes. They dry out more rapidly than do north slopes. The dry leaf litter is more easily blown away and accumulates in coves and elsewhere.

Photo by U. S. Forest Service.

On stony slopes the removal of litter results in destructive erosion.

Litter accumulation is therefore not favored on the south slopes and consequently humus formation is not favored. Furthermore, the south slopes are more frequently burned over because of their dry condition, and these fires have reduced to a minimum the amount of humus which may form. Erosion and leeching are then favored by the absence of organic material in the soil. Nevertheless, soil conditions on the south slope may be adequate to supply the necessary mineral nutrients for forest growth, providing other conditions can be met. The absence of humus accumulation because of repeated fires, etc., may therefore be the limiting factor. As is shown in the above table, the forest floor of the south slope is also deficient in water retention. Moisture retention would certainly be favored by an increase in the humus content, and precipitation in this region is quite adequate for forest growth. Hence loss of timber production on these south slopes may be attributed chiefly to fire and litter relations.

It may be concluded from the above discussion that the forest and the forest soil, with its great society of micro-organisms, must be in harmonious balance if maximum timber production is to be expected. Throughout the Southern hardwood region of the United States this balance can be maintained only when leaf litter is protected from fire and when management of the forests includes due consideration for those important environmental conditions favoring litter decomposition.

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