

Some Forest--Soil Relationships

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A forest soil and the mature forest growing upon it are in a state of dynamic equilibrium. This implies mutual interaction between them, but the forest undoubtedly is the dominant force. A certain type of vegetative cover always tends to build a soil better and better suited for its own growth the longer it occupies a given site. Thus, forests tend to produce soils especially suited for the growth of trees; prairie vegetation tends to produce soils best suited for the growth of cereal plants, and so on. The dominating influence of the vegetative cover is so strong that it definitely determines the character of the soil profile. This fact has led to the most recent conception of soil formation which insists that a soil results solely from the activity of organic life. Weathering processes only produce the parent material from which soils are developed. Weathering is essentially a destructive process. Soil formation is a constructive process. Weathering processes cause a breakdown of minerals, a solubility of basic materials and a leaching away of soluble salts, resulting in the development of secondary minerals of greater stability but of lower nutritive content. Organic life, in contrast, tends to conserve nutrient materials in an organic form from which succeeding vegetation can obtain what it needs and it, in turn, leaves further organic residues. Finally a state of equilibrium is reached where the annual increments of organic matter to the soil just equal the annual decomposition. At what point, in terms of percentage, that this equilibrium is reached is dependent upon at least five factors according to Coile: forest type, stand density, age of stand, soil texture, and soil moisture supply.

Widely different soils may occur in the same territory depending on the kind of vegetative covers that were associated with them. Palouse soils differ from the Helmer soils in this district, not because of differences in parent material, but because the former developed under grass vegetation, and the latter under a forest. It is obvious that the vegetation will also be influenced by the soil which develops under its regime. The soil provides the tree with (1) stability (2) space for a root system (3) moisture (4) nutrients. In carrying out these functions, the soil is changed by the forest so that it can serve best the particular species growing there. Thus, we find certain relationships existing between forest types and soil types. The more severe the environment, the more clear this relationship is. In regions like western Washington where the only unfavorable feature of the environment is the dry summer period, there are only faintly developed relationships, occurring for the most part on sites which intensify the general climatic conditions, particularly the moisture conditions.

From the practical standpoint, as Toumey and Korstian point out, there are marked differences in the use of soils by foresters and by agriculturalists. To the forester, the humus layer of the forest is the keystone of successful forest management.

"Organic matter in the forest serves the same purpose as tillage in agriculture. Agriculturalists maintain soil fertility through the use of crop rotations and the application of fertilizers; foresters by the maintenance of desirable humus conditions. It is as much the task of foresters to develop and maintain a normal forest soil as it is to

**MINERAL SUBSTANCES TAKEN ANNUALLY FROM ONE ACRE
BY VARIOUS FIELD AND FOREST CROPS**

Crop	Ash lbs.	K ₂ O lbs.	CaO lbs.	MgO lbs.	P ₂ O ₅ lbs.	SO ₃ lbs.	SiO ₂ lbs.
Field							
Cereals	186	28	14	9	21	4	100
Legumes	173	44	44	11	27	9	9
Potatoes	231	107	36	18	32	14	8
Grass Hay	294	71	44	18	27	11	107
Average	235	78	43	17	28	11	37
9 crops							
Forest							
Beech*	194	13	89	15	12	4	56
S. Fir	123	16	75	10	10	4	8
Spruce	138	8	62	8	7	3	45
S. Pine	52	6	24	5	5	2	6
Average	126	11	62	10	8	3	29

*(Wood and leaves)

Noteworthy differences are:

1. More total ash in field crops.
2. More K₂O in field crops.
3. More CaO in forest trees.
4. More P₂O₅ and SO₃ in field crops.

obtain regeneration and make necessary cleanings and thinnings." The normal forest soil mentioned by Toumey and Korstian is one whose organic layer is in a state of dynamic equilibrium with the environment.

To further orient ourselves with respect to the nutrients required by forest trees as a crop, compared to common field crops, an illustration from a table reported by Schlich is useful.

It must be remembered that time for removal of these nutrients from soils is also a factor in these comparisons. Trees probably are carrying on active growth processes from the time the leaves unfold in the spring until the leaves drop in the fall, while many of the field crops must germinate, grow to maturity, and be harvested in from twelve to sixteen weeks. The forest trees, therefore, take a long time to obtain a notably smaller supply of nutrients from the soil than field crops take to obtain a relatively greater quantity. This may account for the fact that the forest can do quite well on sites

where general crop production would fail.

It is only natural for both foresters and soil investigators to interest themselves in the forest litter, or humus layer, since the fertility of the forest and the development of different types of soil are both dependent upon the character of this material. An indication of the interest in this matter is given by the organization of a symposium in the 1937 meetings of the Soil Science Society of America by John T. Auten of the Central States Forest Experiment Station dealing with the different kinds of humus layers developed in different parts of the United States. Monoliths were sent in from all parts of the country and studies made of their characteristics in an endeavor to develop some sort of classification of humus layers which would fit conditions everywhere. It is suggestive of the close relationship between soil types and forest types that the symposium concluded that the soil series names could well be used as descriptive names for the forest humus layers

developed on them. Thus, the names take the form Muskingum duff mull, meaning duff mull produced on the Muskingum soils.

Notwithstanding the obvious difficulty in classification of humus types, which is generally mainly the result of not knowing enough about what we are trying to classify, there is much information of great interest to both soil scientists and to foresters concerning the relation of different types of forest litter and soil formation processes. This relationship is mainly concerned with the products of organic breakdown which enter the soil.

Studies of the decomposition processes of the leaves of different species of trees and bushes have been made at many places. I wish to quote one of the most recent of these studies, made by N. N. Stepanov at Moscow, USSR, and reported at the Second International Congress of Soil Science in 1930. Leaves of oak (*Q. pendunculata*), maple (*A. platinoides*), poplar (*P. tremula*), mountain ash (*Sorbus aucuparia*), cherry (*Prunus padis*), white birch (*B. verrucosa*), basswood (*T. parvifolia*), red elder (*Sambucus racemosa*), spindle tree (*Evonymus verrucosa*), buckthorn (*Rhamnus cathartica*), cranberry tree (*Viburnum opulus*), hazelnut (*Corylus avellana*), Siberian pea tree (*Caragana arborescens*), Scotch pine (*P. silvertris*) and Norway spruce (*P. exelsa*) were collected and allowed to decay in large lysimeters outdoors for eleven months, meanwhile collecting the rain and snow water which percolated through them. The results are summarized as follows: The first percolation was acid in reaction [maple (4.3)*, spindle tree (5.3), poplar (5.4), Scotch pine (5.4), Norway spruce (5.5), cranberry tree (5.5), oak (5.6), elder (6.1), hazelnut (6.2), mountain ash (6.6), cherry (6.7), caragana (6.9)]. Following percolation waters became more and more alkaline, showing

the release of more and more basic materials as decomposition proceeded. At the end of seven months, percolates read: elder (8.3), cranberry tree (7.8), cherry (7.7), buckthorn (7.7), caragana (7.5), spindle tree (7.3), white birch (7.1), Norway spruce (7.0). After eight months, basswood read (7.7), hazelnut (7.4), and mountain ash (7.4). Three kinds of leaves never passed the neutral point—maple (6.56), Scotch pine (6.77), and oak (6.92).

The influence of the different reactions of the percolate on the mineral substances during soil formation can be readily understood from this experiment. Under a process of continued acid leaching such as occurred under maple, pine, and oak, the iron compounds will be soluble and will pass downward in the soil. This will result in a bleaching action of the upper layers of soil and a tendency for the process known as podzolization to occur. On sandy soils, this acid leaching will develop the true podzol soil with an ashy gray subsoil layer and a brown hardpan beneath it.

On the other hand, this process could not take place on the same site if alkaline percolation waters were developed from poplar, mountain ash, cherry, birch, basswood stands. Here the iron would remain in place, no bleaching would occur, and "brown earths" would develop. As Stepanov points out, the influence of the shrub undergrowth in forests may be a profound one in so far as soil development and soil fertility are concerned. He shows that wide differences exist in the amounts as well as in the rapidity with which mineral plant nutrients are liberated by decomposition processes. Since some of these nutrients were obtained from the subsoils, and now become a part of the surface humus layer, the forest brings

(*Refers to pH values.)

about a circulation of basic material within its soil and thereby markedly affects its own site. Just as long as there is enough basic material available to the trees in the subsoils, the soil development will be a favorable one, but if, through wood production, enough basic material is tied up and taken out of circulation and the subsoil supply becomes exhausted, then a new, more acid regime will set in with its resultant decrease in soil fertility and a new succession of species may take place. The artificial planting of a tree species that has a low content of basic material in its leaf litter, on a site formerly occupied by trees with highly basic leaf litter, may also bring about a degradation of a once fertile soil. In eastern United States, instances have been cited of the formation of an insipient podzol soil within a hundred years after a stand of white pine had been planted on an old beech forest soil. This illustrates how intimate the relation is between soil formation and forest types.

The quantity of leaves produced per acre per year by different trees of mature age has been estimated by Ebermayer—beech 3330 lbs. per acre of dry matter, spruce 3000 lbs. per acre of dry matter, and pine 3186 lbs. per acre of dry matter. These quantities are about equivalent to six tons of barnyard manure. The weight of dry matter added to the forest floor annually varies, however, with the quality of the habitat. For the same species, Ebermayer found:

Site quality	I	II	III	IV	V
Leaves lbs./acre	3047	2213	1462	1149	617

The influence of the depth of litter in forest stands in the Middle West has been shown by Auten. He obtained a good correlation between depth of humus soil and annual growth rates. He found no relationship, however, be-

tween available mineral nutrients and growth rates. This is probably a result of the time factor which permits more leisurely absorption by trees.

It is probable that the supply of nitrogen in the forest is the most important single factor in its nutrition. Ebermayer has estimated that an acre of forest trees require from thirty-five to fifty pounds of nitrogen annually. The source of this is difficult to determine. Fallen leaves going into the forest litter contain about 1% nitrogen so that if all of this became soluble during the next season, the trees would be amply supplied, but some insoluble humus containing nitrogen is also formed. Perhaps, however, when the forest soil and the tree growth is in equilibrium, the needs of the trees are met by the annual breakdown of organic matter. This points to the necessity of maintaining the maximum humus layer possible to absorb the rainfall and to avoid nitrogen losses through leaching and runoff.

Certain trees, like the alder, are able to obtain nitrogen from the air by symbiotic nitrogen fixation processes. Root nodules on these trees are often very well developed and older trees have been grown for several years on a nitrogen free nutrient medium. This probably accounts for the ease with which this tree occupies humus-free sites like fresh road cuts, gravel pits, and old railroad grades in western Washington. Alder is also capable of building a rich litter, as is indicated by the preference new settlers show for the so-called alder bottom soils. Investigation of a large number of such bottoms shows that in soil texture, water holding power, and general desirability, such sites may be markedly inferior to soils growing other forest species and the adaptability of alder to poor sites really accounts for its presence there. It is a very poor indicator of good soil. Scotch broom is also

a legume which can successfully grow on poor soils. It is sometimes used in Europe as an under cover to incorporate atmospheric nitrogen into the soil for use by the forest already established.

The natural liberation of available nitrogen from forest humus layers is closely bound up with the ratio between carbon and nitrogen in the material. A group of uncropped cutover and virgin soils in western Washington averaged 21.8 for a C/N ratio, while most cultivated field soils have a ratio of approximately 12. It has been shown that the more narrow the C/N ratio becomes, the more available the nitrogen is. Here then is another illustration of the tendency of a given form of vegetation to produce a soil condition most suitable for itself. Forest trees need a small amount of available nitrogen over a long growing season, a condition which will occur with wide N/C ratios. Field crops need a relatively large amount of nitrogen in a short period of growth, and the organic residues in field soils have a narrow N/C ratio to meet the crop requirements.

In view of these considerations, it is apparent that the forester and the soils man have a common ground upon which much of the success in soil management, either for forests or for field crops, depends. This common denom-

inator of interest is the soil organic matter represented by the forest humus layers.

There are probably a great many other forest-soil relationships that we know nothing about, for they have not yet been encountered and will not be until more attention is given to this inter-relationship between the soil and the forest. To a very great extent, the foresters have not, in this country at least, recognized the fact that the soil is so important in the production of the forest and that the forest determines so definitely the formation processes of the soil.

Granting that this forest-soil relationship is important, what education in soils should a forester have? Should we take a soils man and try to make a forester out of him, or should a forester be trained more adequately in soils? It is likely that the latter is the course to be chosen generally. In addition to the usual introductory courses in soils, it would seem desirable to include as much other soils training as can be conveniently carried. As a minimum requirement in this connection, however, soil classification or pedology and soil fertility should be absolutely required. Enlarged academic training of that rare hybrid—the forest soil man—should profit both sciences.