The Biological Task of Forestry

PART II

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The Humus Layer and Forest Soil Biology

Humus is the forest compost and the role of biological decomposition is no less vital to its cycle than in garden compost. The early advocates of the humus theory of plant nutrition recognized in a general way the importance of organic matter in the soil, but the prestige of Liebig and his students caused such a violent swing of attention to mineral nutrients that the science of soil biology was retarded until the work of Pasteur, Winogradski and other pioneers demonstrated the activity of microörganisms in nitrogen transformation. The outstanding importance of earthworms in working over the soil and improving its physical as well as chemical condition was shown by the classical studies of Darwin (1882) unequaled in modern researches. The appreciation of their influence on forest humus was given impetus by P. E. Müller (1887) in Denmark, who gave the name "mull" to the type of humus in which the organic detritus is mixed with mineral soil by certain soil organisms effective also in keeping down fungi and favoring bacterial activity. Humus types conditioned by fungi were called "mors." Recently Romell and Heiberg ('31) and Bornebusch ('32) have made more detailed classifications of these groups.

The epoch-making study of Hesselmann ('26) on coniferous humus and subsequent studies (Melin, '30; Jacot, '36) only showed that the answer to many puzzling questions of humus formation must be sought in the activity of microörganisms and he dispatched Romell to study them under Winogradski. While working in Hesselmann's station at the time, the writer recalls vividly a visit to Denmark when the late Prof. Oppermann introduced Dr. Bornebusch, then beginning his study of forest soil fauna which was published 7 years later (Bornebusch '30). The recital of investigations of forest soil biology could be continued indefinitely, and the vast literature represents a science in itself. It will suffice to mention a few more recent demonstrations of the importance of soil organisms.

The mull type of humus, which was proven to represent the best condition for fertility is, as already pointed out, preëminently the result of earthworm activity, although other forms such as myriapods (Romell '35) occasionally may be very effective. Recent studies by Johnston ('36) indicate that whereas mor or compact humus types may actually have larger total faunal populations, the feeding activity of earthworms is greater in the mull and results in the most effective working in the soil. Presence of suitable earthworm food in the leaf litter seemed important, and the soft-foliaged species such as ash, alder, birch, aspen and basswood were reduced by worms much more rapidly than oak, beech, or pine. His studies show 45,000 to 135,000 macrofauna per square meter in mor humus under white pine and but 27,000 to 62,500 in mull under mixed hardwoods, but the number of earthworms was greater and their weight 3 times as great as in the mor. The total weight of all organisms was also greater. The beneficial effect of the ash tree is further demonstrated by the findings of Wilde and Patzer ('40) in a study of soil fertility characteristics of soils beneath virgin stands of northern hardwoods that under ash 90% of the available nitrogen was in the form of nitrates (cf. also Broadfoot & Pierce '39). These studies emphasize the need in forests for an abundance of soft-textured foliage which can be used by earthworms. It may be of decisive importance in maintaining suitable humus types. Favorable moisture conditions may partially compensate, however, as often noted in Sweden and recently reported by Johnston ('40) where an abundance of worms was found under a pure stand of red and white pine.

The Role of Small Mammals

Mammals also may be beneficial in working the soil by their burrows, which allow water to percolate easily into the soil and give aeration as well. Hamilton and Cook ('40) report upwards of 300 individuals per acre in mature mixed hardwoods and point out the additional benefits derived from the aid of these creatures in controlling injurious forest insects. The destruction of spruce forests in the Northeast and Canada during the past decade by the European spruce sawfly has given prominence to the action of small forest duff inhabiting shrews in eating the cocoons of this insect, in some instances consuming 80% of the cocoon population. Despite the erroneous assumptions which often accrue from data on stomach analyses alone it must be conceded that small mammals do exert a considerable effect on forest insects as well as on the physical condition of the soil. They are occasionally troublesome seed eaters but disseminators of seed also. Limits need to be kept on their numbers by a normal population of predators such as hawks, owls, foxes, etc.

The whole subject of humus transformation and forest soils should be attacked from the biological viewpoint. Yet this continues to be ignored in many careful investigations of forest soils. As Romell ('35) states:

"Biological explanations have been offered as supplementary . . . but never as a common explanation of the activation phenomena. It has even been stated repeatedly that no biological explanation seemed possible . . . In the writer's opinion this is a fundamental misjudgement."

Indeed the importance of biological life goes far beyond the activation of the humus layer itself. CO_2 liberated by these organisms supplies the chemical forces necessary for disintegrating mineral soil particles and making available to plants the mineral ions proven necessary for their nutrition. The atmosphere directly over forest soil having abundant biological life is enriched with CO_2 as found by the researches of Gut ('29) and others, so that the concentration of CO_2, usually a limiting factor in photosynthesis, is increased to the great benefit of young tree seedlings. Thus the influence of biologically active humus and soil extends not only to the nutritive functions of tree roots but to the aerial parts as well and to animal and bird life.

Disturbances of the Biological Balance in Forests

The theoretical ideal of the virgin forest where growth balances decay and fauna and flora maintain themselves in harmony and stability rarely if ever exists for long even in undisturbed nature. Trees mature and blow down in cycles and as groups. Hurricanes and lightning-caused fires have occurred repeatedly in prehistoric and recent times; insects multiply in cycles just as their natural enemies are affected in turn by cyclic fluctuations in the populations of their predators. All these perhaps are ultimately controlled by sunspot cycles.

Man-caused disturbances are of more direct interest. I need hardly dwell upon the influence of forest fires, which often destroy every vestige of soil as well as vegetation. Some recent studies of the effect of fire upon soil fertility and biological life in the soil are worth noting, however. Even light surface fires destroy the litter of dry leaves and twigs and reduce the organic content of the soil which results in a decrease in soil organisms. Soils laid bare by fires are subject to erosion; they become compact, seedlings are destroyed and annual weeds and grasses supplant more tolerant trees.

1. *Fire.*

Periodic burning at 3 to 5 year intervals of the grass and weed vegetation in longleaf pine stands seems to be accepted as good practice where natural regeneration of longleaf pine is desired since the fire helps to control the brown spot needle blight (Wolf & Barbour, '41), which seriously injures the fire-resistant seedlings. Yet even here Heyward and Tissot ('36) found burning injurious to soil fauna. Unburned soils were excellent habitats for microfauna, being "riddled with holes and tunnels of small mammals and insects, a condition generally lacking on frequently burned areas."

"The A_0 horizon of unburned areas contained approximately five times as many microfaunal forms as the ground cover of burned areas. The top 2 inches of mineral soil of unburned areas contained eleven times more such animals than the corresponding soil depth from burned areas . . ."

That the same forms of organisms were found on burned soils, although in lesser number, is attributed to the slight depth (¼") to which lethal temperatures penetrate with light surface fires.

Another exception where one light burning has been suggested as beneficial is in the coastal region of northern Sweden where the extremely deep accumulation of duff in a moist and cool climate results in a matted humus on cold soil inhospitable to the establishment of tree seedlings. These soils are also quite barren of microörganisms and one burning may be helpful in activating the humus by removing shrubby vegetation and permitting the sun to warm the soil (cf. Källström, '26; Eneroth, '28).

The deterioration of forest soils following fire is often paralleled in lesser degree by the localized effect of slash-burning. Disposal of logging debris by burning is often advisable because of the fire hazard created if it is allowed to lie and dry out. In the far West this often amounts to virtual broadcast burning of everything on large areas, comparable in deterioration of the soil to that of forest fires. While brush disposal by burning may occasionally be justified to reduce an extraordinary fire hazard, there is no excuse for it as standard practice. The fault is with the method of cutting which allows such heaps of slash to accumulate and dry out. The writer has carried on partial cuttings in spruce-fir, hardwood, and white pine forest types for 20 years where lopping and scattering the slash with close utilization allowed the slash to lie close to the ground, and the settling of the snow crust in spring carried it even flatter. Never once was it necessary to burn slash. During salvage of a 100 acre stand of pure white pine on the Fox Research Forest in Hillsboro, N. H., which was completely flattened by the hurricane of 1938, a good occasion was given to compare burning slash and merely scattering. Four acres were completely cleared and all slash burned by a WPA crew; the remainder was cut and skidded by a contractor, who utilized all logs to 5" top diameter. He was not required to lop branches from tops or otherwise dispose of slash, but found it necessary to do some clearing of this sort. After completion of logging the slash was found to be so completely cut up and scattered that it was not considered necessary to do any further work. Counts of tree reproduction on this area in 1940 showed a substantially higher stocking of white pine and hemlock seedlings than on the burned area. Shelter afforded by slash is beneficial in protecting small seedlings on denuded areas, as well as conserving soil moisture and favoring normal decomposition of the litter and humus.

Burning is also injurious to adjacent standing trees as well as to the soil and seedlings. Bark and branches are scorched no matter how much care is used. Usually such injury does not show up until after many months or even years. The colder the weather when the burning takes place the more liable trees are to injury due to rapid thawing of cambial cells. One of the worst features is that burning slash piles is itself the very worst possible fire hazard. Every year a high percentage of forest fires is caused by slash burning. The cost of suppression of these fires alone would go a long way to aid proper lopping and scattering of slash so that it will act as a "green-manuring" of the forest. Hazardous areas should be patrolled, not burned. Forest fires and slash burning are therefore the first problem to be overcome in order to make forests true soil conservers and biologically healthy and productive.

2. *Cuttings.*

Logging operations are unquestionably severe disturbances of the forest, and are devastating if followed by fire or erosion. But they need not be biologically wholly bad in their influence. It is rather the manner and the extent of cutting which may be disturbing. Moreover, cutting of forests is fundamentally necessary for the healthy growth of trees and to keep the soil and fauna also alive and healthy. Small openings in the forest caused by clearings or group selection cuttings furnish needed browse for deer and rabbits (Mather *et al.,* '40). Periodic thinnings are necessary in all cases. It is only widespread clearings and complete liquidation of the forest capital which are injurious. Cutting is necessary to furnish wood products for man's use, to supply tops and slash as browse for wild life and green-manure for the soil. Disturbances caused by cutting should be so ordered as to be beneficial rather than otherwise.

3. *Unhealthy forest conditions resulting from improper establishment or tending of stands.*

Reference has already been made to the barren habitat offered wild life in pure coniferous stands and the reactions which sometimes occur as a result. The classic example usually given is that of pure stands of spruce in Saxony, artificially established on relatively heavy soils of the brown soil group. High hopes were held for rapid growth and production. Such forest ought to be financially the most profitable, it was believed. With advancing age soil deterioration was noted, accompanied by slackening in growth, incidence of root rot, insect outbreak and other symptoms of unsoundness in biological structure. Yet we continue to make pure plantations of conifers!

There are justifications for pure plantings on small areas, however. Plantations are expensive, and stemwise mixtures have not been successful, since one species always grows faster than its neighbor and suppresses it. There is a place for planting in good silvi-culture but a minor place; in reclaiming abandoned farmland or burned land the first crop will inevitably be poor. Only when a new humus layer has been established can real forest production begin. Excessively scrubby Scotch pine plantations in New York State have yet justified themselves by their function as a nurse crop, preparing a seedbed for white ash and other desirable species which have followed. If pure coniferous plantations are thinned early and often enough, hardwoods encouraged in mixture, they are surely efficient soil reclaimers.

Recent studies by Dr. H. H. York of the University of Pennsylvania are especially interesting in this connection. Severe pathological and physiological disturbances were found in 20 to 25 year old plantations near Rochester, N. Y. Where trees were pruned and the branches allowed to lie on the ground and decay the trees were in much better condition than where the branches were raked up and burned or carted away in the misdirected effort of relief crews. Physiological disturbances manifested in extra-seasonal growth of shoots, abnormal polarity of branches, resulting in forking, and vascular infections were traceable to forest nurseries where stock had been grown year after year on infected soil and with improper soil management.

4. *Grazing by domestic live stock.*

Grazing by cattle and sheep usually means excessive grazing at least on limited areas, with attendant erosion and soil deterioration. But even light grazing is injurious to the forest. Cattle browse the soft-foliaged hardwoods by preference, so that these, the species of highest value as soil builders, are practically eliminated. We owe our pure second growth stands of spruce and white pine in the Northeast to grazing, and unquestionably some of the yields in cubic volume are higher than if the hardwoods had not been eliminated by cattle; but health and quality of the forest have suffered, as a glance at the branchy weeviled trees indicates. Grazing kept the young conifer stand much too open and the low density prevented early crown closure and self pruning; but worse still the lack of shade and trainers enabled the white pine weevil to make wholesale destruction of the leading shoots. The crooked, forked stands represent a loss in dollars and cents attributable to pasturing of cattle, greater in the writer's opinion than that caused by forest fires in the same interval. Yet this enormous damage caused by grazing passes unnoticed. Hardwood stands also suffer; low density in sugar maple favors inroads of sugar maple borer for instance, and Nectria canker, root rots and deformities of all kinds are much more prevalent in stands which have been grazed.

Measures Conducive to Optimal Forest Productivity

1. *Mixed composition of stands.*

There is little doubt but mixed forest, composed of several different species, can utilize the site more efficiently and fulfill the biological ideal better than so-called monocultures. The soundness of the movement in this direction initiated by Karl Gayer and his school has been confirmed by modern research. Mixed stands are good insurance against insects and diseases which almost always build up to greater proportions in pure stands. Experience has shown that quality of individual trees is better when they are associated with different species. In every case mixed stands suffered less than pure stands in the recent New England hurricane. Wild life of all kinds finds food more accessible in mixed stands where organic life is more abundant. Unlike pure stands, which require expensive cultural effort to bring about, mixed stands develop naturally under the guidance of the forester's marking axe.

2. *Frequently recurring light cuttings.*

Trees need to be given additional growing space little by little as they grow older. It is significant that the very frequent thinning of spruce practiced in Denmark coincides with exceptional biological activity in the soil. One leads to another and these forests are among the most highly productive in the world. Rapidly growing stands need cutting at more frequent intervals than slow-growing ones, and the way to encourage fast growth is to thin often but lightly.

3. *Natural regeneration.*

Natural seeding is superior to planting from almost every angle, and is usually easy to secure with a plentiful seed supply once the soil and humus have developed favorably under the maturing stand. Reproduction should appear inevitably as thinnings succeed one another. Clear-cut areas lacking this advance reproduction are prone to grow up to light-demanding species. No areas should be cut clear until the desired "advance growth" has appeared.

4. *Scattering slash: Prevention of slash burning as well as forest fires.*

It is the forester's task to aid Nature's fertilization processes by "green-manuring" or scattering branches in such a way that wood-destroying fungi will break them down rapidly and the decaying matter come to the use of soil organisms promptly. Experiments have shown that hardwood slash supported a foot or so above ground rots faster than directly on the ground. Coniferous slash is generally best kept as near the ground as possible. The second requirement of slash disposal is that it act as shelter for, but not crush or smother the young tree seedlings which it is desired to favor. In felling trees, care should be used to drop them away from clumps of reproduction, and to avoid windrowing slash in deep piles. Most of the difficulties with slash arise from heavy fellings of a more or less destructive nature. Forestry operations in restricted clearings or partial cuttings do not require concentration of slash to make logging economical.

5. *Maintenance of conditions favorable to wild life.*

Annual cuttings provide slash tips and sprouts required by deer and rabbits, and slash accumulation provides ideal nesting places for grouse. Small clearings and openings furnish the forest margin habitats so desirable for many birds and animals. The type of silvi-culture I have indicated therefore fits in well with needs of wild life. In addition a balance must be maintained without extermination of predators on the one hand (house cats might well be eliminated), nor too great restriction of kill or game species. Saving ponds, brooks and swamps in their natural condition, and allowing native berry bushes to remain will prove more successful than artificial attempts to introduce them.

6. *Elimination of forest grazing.*

Pasturage of domestic live stock has no place in forest management. It is anomalous that grazing is a major activity on some national forests in the West; this is only because the Forest Service is the most effective agency for administering the grazing resource on public lands in that particular region. These grazing lands are not properly forest lands. Grazing on timberlands results in no good, especially to the cattle, and destroys the soft-foliaged hardwoods so necessary to forest soil fertility. In the central states and East grazing should be restricted to fenced and seeded pastures, and the supervision of grazing is no more the function of a forester than other farm operations.

7. *Conservation and upbuilding of the soil.*

The ultimate natural resource is the soil and it is believed this will best be maintained and improved by the preceding measures. These will provide the protection against erosion, floods, wind and other natural hazards, and foster a natural process of storing up fertility against such time as it may be needed for agriculture, yielding at the same time the maximum amount of products for use consistent with sustained production.

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