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SOIL CHANGES AND SILVICULTURE ON THE HARVARD FOREST

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Since its establishment in 1908, the Harvard Forest has dealt primarily with a type peculiarly characteristic of central New England, and one which, on account of marketability and apparent productiveness, has been taken as the chief objective in the development of regional forestry—the white pine (*Pinus strobus* L.) stands that seeded in on thousands of acres of farm land abandoned during the middle and latter part of the last century. In addition to this—the prevailing type—the Forest contains stands representing two other kinds of origin: first, several small areas of virgin forest, uneven-aged hardwood mixed with hemlock (*Tsuga canadensis* (L.) Carrière) and some white pine; and second, blocks of even-aged second growth, either hardwood or mixed hardwood and pine, which originated from the clear cutting of the virgin stand.

With these examples of varying life histories for comparison, it early became apparent that white pine in pure stands was a transition type, or intermediate stage in the succession, and one not in the long run suited to the comparatively heavy soils of the region. Always containing a variable admixture of hardwood, these forests develop in later life not an advance growth of pine, but one of broad-leaved species, such as white ash (*Fraxinus americana* L.), red oak (*Quercus borealis* Michx., formerly designated *Q. rubra* L.), sugar maple (*Acer saccharum* Marshall), black and yellow birch (*Betula lenta* L. and *B. lutea* Michx.), red maple (*Acer rubrum* L.), etc. This advance growth is not only a serious obstacle to the reproduction of the pine by any method of cutting, but an index of a strong tendency toward reversion to the original, or virgin, type. On the other hand, the pine stands themselves do not exhibit a satisfactory condition. They prune themselves slowly, seldom produce any but low grade lumber, and at the age of 50 to 60 years almost always show a sudden decline in growth, together with increasing evidence of ill health. Both prolonged observation, as well as systematic studies of stand development (Harvard Forest bulletins 7 and 8), have established the conviction that the conversion of the old field white pine type into mixed stands is, on the score of productiveness, quality, and cost of formation, the best policy.

Thus, the annual cuttings in the white pine type have had for their object either the formation of a mixed stand of the best hardwood species or a

mixture of hardwood and white pine. On areas where the advance growth of ash, oak, etc., is sufficiently abundant, the operation consists merely in one clean cutting of the stand, accompanied by complete disposal of limb wood and slash, either for fuel wood or by burning. In cases where the advance growth is less abundant or satisfactory, an admixture of white pine reproduction has been secured by one preparatory or seed cutting, followed after four to six years by the removal of the remaining stand. Or, if natural reproduction seems unlikely on account of an unfavorable seed bed, a clear cutting is followed by the planting of pine in groups or small patches where the soil is favorable and hardwood advance growth is scanty. Thus in some operations the previous stand is removed at once, and in others it is taken off in two cuts from four to six years apart. In both cases the subsequent conditions and treatment of the reproduction area are alike.

After the final removal cutting there follow from two to four years when the ground is more or less exposed to the sun and the elements. This exposure, however, diminishes very rapidly with the successive development of several strongly marked phases of vegetation. In the second year a dense growth of hay-scented fern (*Dicksonia punctilobula* (Michx.) Gray) with annual weeds and some grasses nearly covers the surface. In the third year *Rubus*, particularly high bush blackberry (probably *R. allegheniensis* Porter) and raspberry (*R. ilaesus* L.) of very strong development, often dominates the ferns and lower vegetation. Meanwhile the hardwood seedlings and seedling sprouts have reached a height of four to eight feet. In the next eight years, two or three weedings or cleanings are applied, the object of which is the earliest possible closing of the cover compatible with desirable composition. This means in practice lopping only such weed trees or stump sprouts of too rapid growth as are likely to suppress the desirable species. Of the hardwoods, whether with pine groups in mixture or not, those chiefly favored are white ash, red oak, sugar maple, white birch (*Betula papyrifera* Marshall), yellow birch, beech (*Fagus grandifolia* Ehrh.), and basswood (*Tilia glabra* Ventenat, formerly designated *T. americana*). In from eight to ten years, depending somewhat on the soil and the density of the young growth, the new stand, now composed almost wholly of the favored species, has established a continuous canopy, which rapidly shades out the ground vegetation, not only most of the herbaceous species, but also *Rubus* and other low shrubs.

That this conversion of type has been accompanied by rapid and beneficial changes in soil condition has been abundantly evident, not only in the strong development of new vegetation following cuttings, but still more in the vigorous growth of the succeeding mixed stands. It is due to Dr. Henrik Hesselman, Director of the Swedish Institute of Experimental Forestry, who has lately visited the Harvard Forest, that these alterations in the soil profiles can here be identified and interpreted in more definite terms.

Most of the areas converted from the old field pine type are located in a block of about 250 acres, where general site conditions are nearly uniform. The topography is a gentle to moderate western slope with only minor dissection into low knolls and hollows and no perennial brooks. The relative elevation is from 750 to 800 feet above sea level. The soil is a light, sandy loam, containing a perceptible element of clay and abundantly interspersed

SOIL PROFILES 1927.

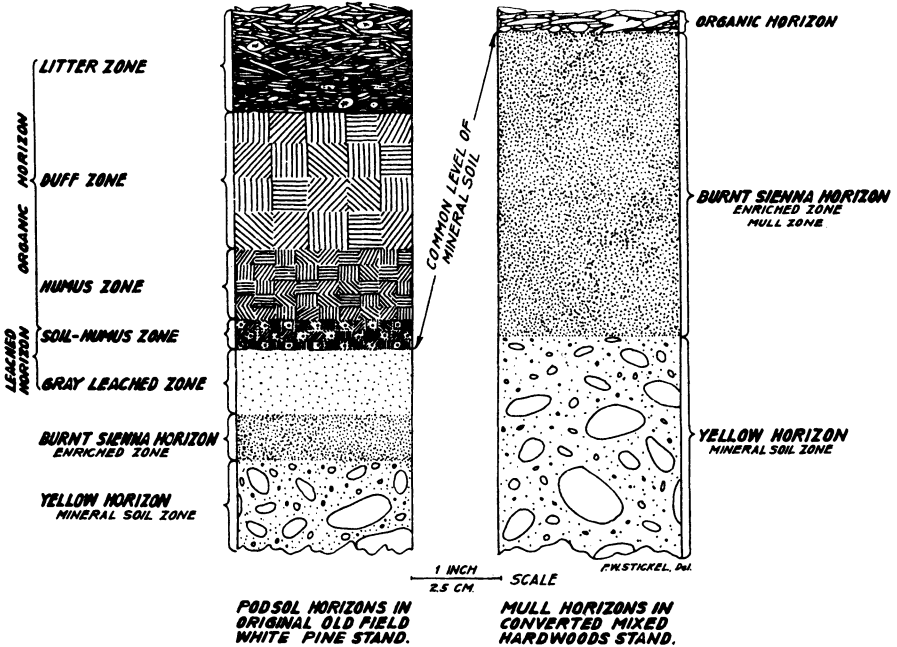


FIG. 1. Soil profiles in 1927, showing change in 18 years from condition of raw humus and podsol (left) under old field white pine, to a true mull (right) under the converted mixed hardwoods.

with cobbles and boulders of gneiss, the principal bed rock of the region. The two stands which, with their accompanying soil profiles, are herewith described may be taken as beginning and end points of the conversion process. The two photographs (Plate I) and the diagram (Fig. 1) show (1) the present condition, both as to stand and soil horizons, of a portion of the original stand which was left uncut, and (2) the converted stand of mixed hardwood with its characteristic soil profile as it appears eighteen years after the clear cutting of the old field white pine stand, then sixty years old. Both the photographs and the drawings apply to locations not more than 200 feet apart, on a site approximately flat, with the old stand adjoining the new one on the west. There are somewhat over four acres of the young mixed hard-

wood stand and two to three acres of the adjacent old field pine type, areas sufficient in size to eliminate the influence of lateral exposure.

The original pine stand, now approximately eighty years old, contains a scattered understory of hemlock and a few hardwoods, yellow birch, white ash, red maple and black cherry (*Prunus serotina* Ehrh.). The soil profile exhibits a distinctly podsolized horizon.¹ Beneath a thin layer of dry leaf litter, chiefly pine and hemlock needles, is a deep zone of duff, composed of raw humus, which merges into the characteristic leached layer. Below this is a thin burnt sienna or enriched stratum, which has remained apparently unchanged, both in depth and organic content, for many years. There is almost no ground cover. Scattered partridge berry (*Mitchella repens* L.), star flower (*Trientalis americana* (Pers.) Pursh.), and goldthread (*Coptis trifolia* (L.) Salisb.) are the chief species. Hardwood advance growth consists of stunted but fairly abundant seedlings of white ash, red oak, yellow birch and red maple. With an organic layer decomposing very slowly and of such depth as to exclude all but the heaviest rainfalls, it is plain that the soil is in a static condition and without active fertility.

Physiological and soil conditions in the young hardwood forest are in striking contrast to those in the original pine stand. The soil on this, as on other similar areas, was identified by Dr. Hesselman as a true mull profile, in which both the heavy litter and organic layer that had accumulated in the previous stand, as well as the current annual leaf fall, have been almost completely decomposed and merged with the mineral soil to a maximum depth of five or six inches. The resulting brown earth closely resembles the best garden loam in porosity, color, uniformity of texture, and moisture content. So active is the decomposition of litter that less than one year's leaf fall remains on the ground, and even this is so thin as to expose the mineral soil over nearly 25 per cent of the surface. Herbaceous ground cover is in general scanty and undersized. The prevailing species are hay-scented fern and a small white aster (*Aster acuminatus* Michx.). A significant factor is the change in the bird population. Instead of the black-throated green warbler (*Dendroica virens* Gmel.), hermit thrush (*Hylocichla guttata pallasii* Cab.) and oven bird (*Seiurus aurocapillus* L.) of the pine wood, the noticeable birds are now the wood thrush (*H. mustelinus* Gmel.), Maryland yellow throat (*Geothlypis trichas brachydactyla* Swain) and woodcock (*Philohela minor* Gmel.), the latter a notable feeder on earthworms. The hardwood stand as a whole is dense and exceptionally thrifty, now at eighteen years old from two to five inches in breast height diameter, and twenty-five to thirty feet in height. Nearly 50 per cent of the mixture is white ash, with red oak, sugar maple, white birch, yellow birch, and scattering basswood, black cherry and red maple making up the remainder. Natural pruning, especially with

¹ The matter of podsol soil will be discussed more fully in the April issue of *Ecology*, Vol. IX, No. 2, by Paul W. Stickel in an article "Podsol Soil: Its Physical Characteristics and Silvicultural Importance. Ed.

ash, has proceeded so rapidly that dominant trees have lost their side branches to a height, in many cases, of twelve feet. The stand appears to combine the highest prospective quality with the maximum rate of growth.

The full interpretation of this striking transformation in vegetation and soil profiles, both as regards chemical and biological factors and practical control under wider variations of site and composition, must await more systematic study; but with so many stages of the conversion process now available on the Forest, there are a few observations and conclusions that may be made already.

The development of the mull profile is complete in from twelve to fifteen years after the removal of the pine.

The rate of development, granted uniform density in the new stand, is affected very little by minor variations in topography.

Given similar drainage, the mull is deepest under ash and sugar maple, less deep under white and yellow birch.

Whether the previous pine stand is removed at one cutting or by a thinning and final cutting six years apart, there is no substantial difference in the rate of soil change.

Extreme dryness or extreme wetness of soil, such as occurs on sharp knolls or in small swamps, appears to arrest decomposition, and therefore to perpetuate the original soil profile.

The debris left from weeding in the young stand, consisting sometimes of stems up to an inch and a half in diameter, has entirely disappeared in from six to ten years.

Small variations in the composition of the previous stand do not appear influential, but a mull horizon seems to develop faster after the cutting of a stand containing 25 per cent or more of hardwood.

Where pine groups up to two rods (10 meters) in diameter are included in the converted stand, the soil—at least after nineteen years—appears to be the same as under pure hardwoods.

In this experience with soil changes on the Harvard Forest, there is a lesson for silviculture. Podsolized soil, except possibly in northern regions where it may be unavoidable, indicates soil deterioration and relatively poor growing conditions. It develops commonly in pure white pine stands, which fall off in growth and health at comparatively short rotations. The mull soil, on the other hand, is fertile and active. It develops rapidly in mixed stands, which have long been recognized, even by lumber operators, to produce the largest and best quality of softwood timber. The natural tendencies of the present transition types in central New England are toward reversion to mixtures of species, which can usually be more cheaply established than pure stands of softwood. There are thus strong biological as well as economic reasons against the maintenance of pure white pine as a permanent type. Conversely, the formation of mixed types means good silviculture and sound business.



A. Original old field white pine stand (control area), now 80 years old.



B. Converted stand of mixed hardwoods 18 years after clear cutting the pine stand. Before cutting, this area looked like *A* above. Note large pine stumps.

SUMMARY

On comparatively heavy soils in central New England, forests of pure white pine (*Pinus Strobus*) develop on abandoned fields as an intermediate stage in succession. These forests, covering a large aggregate area, have been the chief objective in the regional forestry. They show, however, strong tendencies to revert to hardwood, rendering reproduction of pine difficult. They produce only low grade lumber, and decline rapidly in growth and vigor after 50 to 60 years of age.

The conversion of these forests to stands of the more valuable hardwoods, or mixtures of hardwoods and pine, can be accomplished by removing the pine in one or several cuttings, followed about four years later by cleanings or weedings to favor individuals of the desirable species.

The soil profile under a certain 80-year-old white pine stand with almost no ground cover shows a thin layer of dry needle litter, a thick layer of raw humus, and a strongly podsolized horizon, below which is a thin typical burnt sienna or enriched stratum. These conditions are unfavorable.

Under an adjacent 18-year-old hardwood forest, where the soil profile at the time the pine was removed resembled the present profile under the white pine, there is now a true mull profile. The rate of decomposition has become so rapid that not only has the accumulated raw humus merged with the mineral soil, but less than a single year's leaf fall now remains on the surface of the ground. The humus-enriched earth closely resembles the best garden loam in porosity, color, uniformity of texture, and moisture, and contains many earthworms.

The bird population has changed from the black-throated green warbler, hermit thrush and oven bird of the pine wood to other species among which the Maryland yellow throat and woodcock are noticeable.

The hardwood stand is dense, thrifty and growing rapidly.

On lands showing tendencies to hardwoods, mixed stands can be secured more cheaply than stands of pure pine, and, since they greatly improve soil conditions and show thrifty growth, they represent good silviculture and sound economics.