THE STRUCTURE OF FOREST SOILS[1]

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How soil particles are arranged in forest soil directly influences the growth of forest trees. This arrangement of particles and their size and shape, or "structure" of the soil, affect soil porosity and hence aeration. Soil porosity is important to the growth and development of tree roots because it affects the diffusion of oxygen to tree roots and the diffusion of excessive concentrations of carbon dioxide from areas adjacent to tree roots (Kramer, 1949). Coile (1948), in studies of the growth and productivity of stands of loblolly and shortleaf pine, concluded that the site quality of trees is generally determined by soil depth and by physical soil factors that influence moisture availability and aeration.

Soil structure determines the number, size, and continuity of soil pores and is important to both forest and agricultural land because it is related to the quantity, quality, and periodicity of water yield. Studies by Baver (1948) and by Nelson and Baver (1940) have shown the percolation rate of water through soil is largely related to the quantity of large pores in the soil. When there are few large pores, water percolates slowly through the soil. If more rain falls than the soil can absorb, surface water runoff will occur, often causing erosion, sedimentation, and floods.

Numerous studies of water infiltration, water runoff, and sedimentation have shown that water percolates into forest soils faster than it does in agricultural or abandoned agricultural soils (Auten, 1933; Dils, 1953; Hoover, 1950; Colman, 1953; Lutz and Chandler, 1947). Studies by Auten (1933, 1941) in Ohio and in the Central States Region show that forest stands have infiltration rates from 50 to 700 times those of adjacent abandoned old fields. Harrold (1953, 1954) found that a wooded watershed at Coshocton, Ohio had less surface runoff than nearby grassland or cropland watersheds. Dils (1953) studied the effects of mountain farming at Coweeta, North Carolina, and reported that marked increases in water runoff, siltation, and stream peak flow resulted from converting a steep mountain forest watershed to corn and pasture. Rothacher (1953), reporting on the effects of reforestation and the elimination of fire and grazing on the White Hollow watershed in eastern Tennessee, found that these practices had reduced summer peak stream flows 73 to 92 percent and that runoff caused by summer storms was reduced as much as 500 percent without any decrease in the total annual stream flow.

Comparing soil characteristics and land-use methods for forest and agricultural land may help in understanding the reasons for the deteriorated soil

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Structure is an important characteristic of forest soil because it affects both tree growth and water yield. Numerous tree-site-quality studies have indicated that the most productive forest land has deep, medium-textured soils that are loose and well aerated. Studies of both forest and agricultural soils have shown that more water infiltrates and less runs off soils with such structure.

In this paper, general forest and agricultural soil conditions are compared to show the differences in soil structure that result from different cultural treatments and vegetational covers. In general, undisturbed forest soils have better structure than soils that are used for agriculture. The superior structure of forest soil is one of the major reasons for the superior quality and periodicity of water yields from forested watersheds. Reforesting abandoned or submarginal land is urged as a means to improve the water relations of such land.

structure and the poor water yield from some agricultural land. Such a comparison may explain the objectives of many of the conservation practices that are directed toward improving soil structure and increasing movement of water into and through the soil.

Land Use

Forest land is usually land that is too poor, too rough, or too inaccessible to be farmed profitably. In most parts of eastern United States the better land has been cleared for agriculture while the poorer land has been left in forest, or if cleared, has been abandoned and left to return to forest cover. Agricultural land is usually devoted to crops that are harvested annually while forest crops are harvested only at long intervals. The high value of agricultural crops warrants intensive cultural practices, whereas the comparatively low value of the infrequently harvested forest crop warrants less intensive care. On forest areas land management involves cuttings that may include harvest cuts and occasional interim silvicultural treatments.

Soil Properties of Forest and Agricultural Land

A forest soil is a natural or only slightly disturbed material that took centuries to develop under permanent forest cover. A succession of genetic soil layers is present, ranging from the very important surface organic layers down to the mineral parent material. The continual depositing of tree litter upon the ground for many decades has developed the characteristic surface layers of organic matter found in forest areas. Relatively little organic matter is lost by the infrequent and incomplete harvesting done on forest land. The organic matter on the surface and in the lower layers is maintained by relatively slow oxidation resulting from cool, shaded microclimatic conditions and from the lack of the disturbing effects of cultivation used on agricultural land.

On most agricultural land the surface organic layers and surface soil horizons have been mixed and altered beyond identity by decades of cultivation. Large amounts of organic matter and nutrients are annually lost when crops are harvested. Furthermore, the incorporated organic matter decomposes more rapidly because cultivation and high temperatures help speed up oxidation.

When forests are removed and the land is used for agriculture, the soil structure generally deteriorates. This deterioration, evidenced by reduced pore space, increased bulk density, increased compaction, reduced content of water-stable aggregates, and reduced rates of infiltration, has marked effects on surface water runoff, stream flow, and sedimentation.

The structure of forest soils is developed and maintained by many factors of the forest environment. The soil surface is protected from the impact of raindrops because the forest canopy and surface organic layers absorb the energy of falling raindrops. Unprotected agricultural soil, however, is frequently exposed to the direct beating action of raindrops with the result that soil aggregates are shattered and dispersed. Soil colloids are suspended and are washed into and deposited in the larger pores that are necessary for the rapid infiltration and percolation of water.

Organic matter on and in forest soil helps improve and maintain soil structure (Lutz and Chandler, 1947). Organic colloids and materials synthesized by soil fungi and bacteria are important in the formation of soil aggregates (Stallings, 1952). Soils used for agriculture, however, do not usually have enough organic matter in the surface layers to maintain the large populations of microorganisms found in forest soils. Reduced action of microorganisms as well as reduced organic colloid content is thus partially related to the poor structure of many agricultural soils.

In addition to microorganisms a forest soil has a relatively high population of macroorganisms that favors soil structure and produces many large burrows and channels (Lutz and Chandler, 1947). Gaiser (1951, 1952) studied the distribution of tree roots in the soil beneath white oak stands of southeastern Ohio and found that the surface soils had a very high concentration of small roots and that the vertical channels formed by larger roots in the surface and subsoil exceeded 4,000 per acre. The large number of root channels, as well as the excellent structure of forest soils, undoubtedly accounts for the rapid infiltration rates and reduced runoff of surface water so often reported from forest land.

Cultivating agricultural land that is too wet frequently produces cloddy or puddled conditions that cause a decrease in aggregation and porosity (Baver, 1948). Plowing and other forms of tillage may actually crush soil aggregates and thus reduce porosity. Heavy machinery may compact the surface layer of soil. Excessive grazing of both agricultural and forest soil usually compacts the surface soil layers and causes increased water runoff because of decreased soil porosity and water infiltration rates (Auten, 1933; Johnson, 1952).

AGRICULTURAL VS. FOREST SOILS

Agricultural Soil	Forest Soil
DEEP productive soils on level or gently sloping land. Land used for annual crops of high value. Cultivation, fertilization, and land-conservation practices frequently used.	SHALLOW, less productive soils on steep or poorly drained land. Land used for forests with long intervals between harvests. Limited cultural practices include harvest cuts and occasional interim silvicultural treatments.
DISTURBED soils whose surface, organic layers have lost their identity through cultivation.	NATURAL soils with undisturbed organic layers and soil horizons.
INCORPORATED ORGANIC CONTENT USUALLY LOW because of decreased litter deposition, annual crop removal, and increased oxidation resulting from cultivation and increased solar insolation.	INCORPORATED ORGANIC CONTENT HIGH because of continual deposition of forest litter, long intervals between harvest, and lower rates of oxidation.
SLOWER RATES of water infiltration and percoltation than forest soil due to a decreased content of large pores.	FASTER RATES of water infiltration and percolation than agricultural soils because of the surface organic layers, large numbers of root channels extending into subsoil, and a high content of large soil pores.
POORER STRUCTURE than forest soil because of lower content of organic matter, decresed activity of macro and microorganisms, exposure to raindrop action, washing of soil colloids into soil pores, increased erosion, mechanical effect of cultivation and grazing that crush soil aggregates and compact surface soil layers.	BETTER STRUCTURE than agricultural soil because of higher content of organic matter, large numbers of macro and microorganisms that form channels and promote aggregate formation, protection from raindrop action, relatively little washing of soil colloids into soil pores, and large numbers of roots in surface and subsoil layers.

CONCLUSIONS

Most of the land presently used for agriculture in the eastern United States was once occupied by forests; in Ohio, for example, the forest cover has been reduced from an estimated 95 percent to 21 percent. This conversion of land to agricultural use has been necessary for the settlement and development of our country; but, it has frequently caused soils to deteriorate. Change in soil structure, reduced water infiltration, rapid water runoff, erratic stream flow, and downstream flooding and sedimentation are symptoms of the deterioration of much of this land that has been converted from forest to farms.

Soil conservation practices are being successfully applied on many agricultural lands. These practices help to improve soil structure, soil stability, soil hydrologic characteristics, and water yields. Practices such as mulching, crop rotation, terracing, contouring, and strip farming have been remarkably successful in correcting many of the major soil problems of agricultural land.

Many problems still exist, however, especially on hilly land and land marginal for farming. Large land areas in Ohio and eastern United States have been, are now, and will be abandoned and will eventually revert to forest. Much land, now being grazed or cultivated, is considered too poor to warrant spending time or money for the needed conservation practices. This land is responsible for many of the water problems of Ohio and eastern United States. Reclaiming and improving this land should be a major consideration in watershed programs designed to rectify the unfavorable stream conditions of many river basins.

Reforesting is advocated on land not suitable for farming as a means of making non-productive land productive of valuable forest crops. Converting this land to forest cover will improve soil structure, increase water infiltration, and reduce water runoff and erosion.

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