Silviculture Part III FOREST SOILS

Forest soil—the result of all the environmental factors at work on a particular site—is that point in the ecosystem where materials are added, transformed, translocated, and lost through natural cycling activities. Soil provides mechanical support, moisture, and nutrients to trees. BY BEN HOFFMAN

Soil surveys performed by the U.S. Department of Agriculture have examined, described, classified, and mapped soils, providing data on their agricultural productivity and suitability for such uses as roads, trails, development, sewage disposal, etc. These maps and data sheets are available from local Natural Resources Conservation Service offices. Though primarily slanted toward agricultural use, they consider such things as matching harvest systems to soil, evaluating potential effects of disturbance, selecting species for planting, identifying potential for wind-throw, etc. Since soil surveys have concentrated on agricultural lands, information may not be available for some forested areas. Get the maps and data sheets for your property: Familiarity with your soils is an often-overlooked tool in managing your forest well.

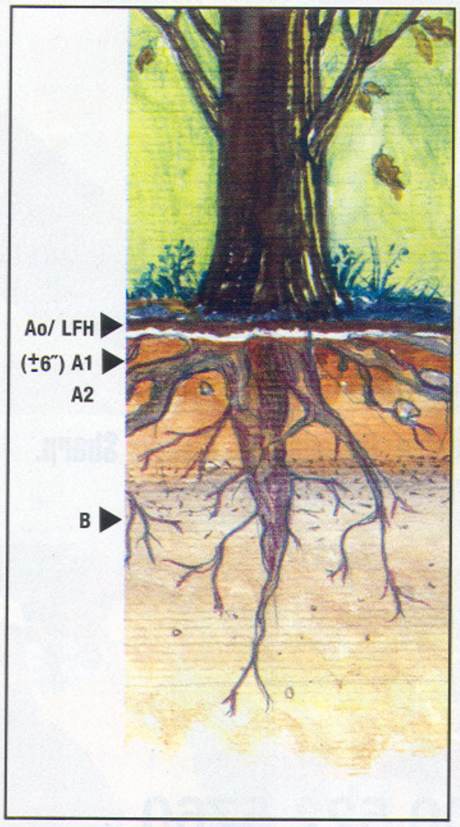

Fig. 1. Profile of a mull soil with hardwoods.

Soil Properties Affecting Plant Growth

Five soil-forming factors—parent material, climate, organisms, topography, and time—determine the major soil properties affecting plant growth, namely, depth, texture, structure, moisture capacity, drainage, nutrient content, organic matter, and topographic position. The easiest to measure are texture, depth, drainage, and topographic position, which are often used to evaluate soil productivity (or site quality). Also, soil color, easily checked with standard color charts, depends on mineral composition, organic matter content, and drainage, and is thus a good indicator of productivity. Topographic position—position on slope and aspect—has a major influence on soil depth, texture, nutrient content, water runoff, and erosion, and is also a good, easily identified indicator of site quality.

Depth is a measure of soil potential for moisture storage and plant-root development. Depth is easily measured with a soil auger and may be limited by a compacted layer, or hardpan, possibly ledge or bedrock, or it may be physiologically limited by drainage. Poor drainage is evidenced by mottling that shows up as yellow, blue, and green discolorations, caused by intermittent, waterlogged conditions.

Depth is often considered in

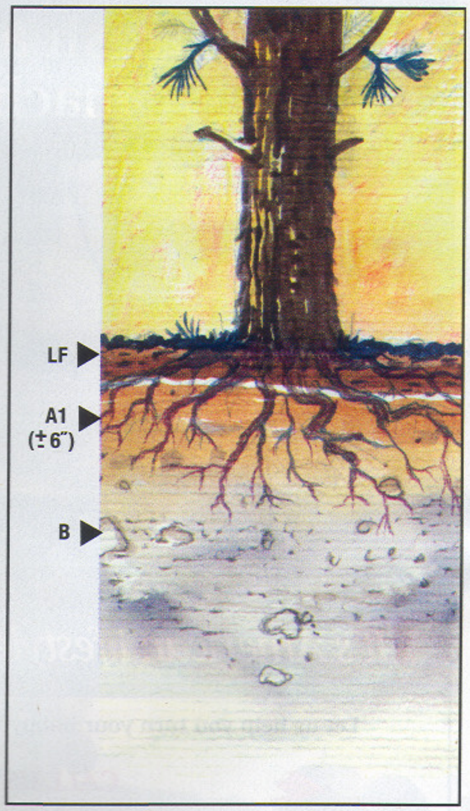

Fig. 2. Profile of a mor soil with softwoods.

terms of the soil profile (vertical cross section), divided into five principal horizons.

O—partly decomposed organic layer over mineral soil.

A—mineral layer below O, with humus mixed in, often affected by disturbance.

B—weathered parent materials, often with minerals/humus translocated from above.

C—parent material, not weathered, except bedrock.

R—bedrock.

The O, A, and B horizons are biologically and chemically active and are affected by soil organisms such as roots, insects, fungi, worms, and any other organisms or activities that cause mixing. Since agricultural cultivation mixes at least the top two horizons, forests developing on abandoned ag land may not show clear horizons. Also, within the O and A horizons, decomposition and leaching of surface organic matter may create recognizable subdivisions. The O horizon may appear as three layers, litter (L horizon), partially decomposed or fermented litter (F horizon), and decomposed organic matter mixed with mineral soil (humus, H horizon).

The A horizon may also have distinct layers. The A1 may be lighter in color because of leaching (by water) of organic and chemical constituents downward. The A2, below, may appear darker in color from the deposits of nutrients leached from above.

Texture refers to the proportions of sand, silt, and clay in the soil and can be estimated by feel. The importance of texture is that the finer the soil, the more moisture and nutrients it can hold. The larger spaces in coarse-textured sands and gravels drain more quickly after rain and are thus drier and hold fewer nutrients. However, fine silts and clays may hold moisture and nutrients so tightly that they are not available to plants in the dry season. So the midrange—loams (a mixture of sands and finer particles)—is best for growth.

Texture influences soil structure, aeration, nutrient capacity, water percolation, retention, and drainage, but also affects root penetrability and seedling emergence. Particle sizes are:

Fine gravel: 1–2 mm, with the least surface area, chemical activity and moisture-storage capacity.

Coarse sand: 0.5–1 mm.

Medium sand: 0.25–0.5 mm.

Fine sand: 0.1–0.25 mm.

Very fine sand: 0.05–0.1 mm.

Silt: 0.002–0.05 mm (often confused with clay).

Clay: less than 0.002 mm, it has the most chemical activity and moisture storage because it has maximum surface area.

For practical purposes, without the proper equipment for sizing soil particles, we can determine sand, fine sand, and silt-clay by feel. Better yet, obtain and use a soil map (caution—there may be variations

A "bedded" pine plantation in eastern Georgia. Many coastal plain soils are sandy and dry but this area was underlain by clay and was poorly drained. By creating raised beds for planting, the new trees were able to become established without drowning during the rainy season.

A drainage ditch in a Swedish spruce plantation. This abandoned farm field was once drained in order to improve its productivity. When farming ceased, it was planted to Norway spruce that reached 16 inches stump diameter in 64 years. It is rarely feasible to drain land for forestry unless it is extremely productive and close to a mill.

An example of poor forestry practice. Full-tree logging removes the slash that normally decays on-site to maintain soil fertility, and clearcutting means little is left. Further, the wide swaths created by the hardwood tree crowns disturb most of the surface soil, making the area especially susceptible to erosion that will remove both soil and nutrients.

within a mapped soil type). The names of soils having more than one size refer to the principal size plus the term loam to denote a mixture. A fine, sandy loam should be fairly productive, but a clay loam may be somewhat better.

Soil structure refers to the manner in which soil particles are arranged, grouped, or aggregated, and affects moisture and gas movement and root penetration. Of special importance is organic matter, such as decomposed leaf litter, needles, twigs, and other debris that improves soil structure by binding mineral grains together. This increases porosity, aeration, and moisture-holding capacity, moderates temperature fluctuations (may even insulate from heat), and provides energy for soil microbes. Organic matter ranges from litter—undecomposed leaves, twigs, etc.—to decomposed humus (like compost) and contains nutrients from the litter and dead organisms that lived in it.

A surprising amount of subsurface activity in the form of annual growth and death of fine roots also improves structure.

The amount of humus and its rate of decomposition are related to species composition and can be influenced by varying the intensity and method of cutting, utilization of woody material, and silvicultural practices (including prescribed burns). In your woodlot, compare the depth of undecomposed litter under hardwood trees, especially mixed stands, and that under pine or spruce. The softwood litter is slower to decompose and often builds up to depths of several inches. Under hardwoods, the litter layer may be very thin, even absent.

Figures 1 and 2 show typical variations in litter layers. A mull soil (Fig. 1) results when the chemical composition of foliage favors rapid decomposition and provides nutrients for soil organisms—bacteria (Southern), fungi (Northern), insects, earthworms—resulting in more rapid incorporation of surface litter into the mineral soil. The H layer (humus) is decomposed organic matter. Hardwood litter added to a mor speeds decomposition, an advantage of mixing hardwoods with softwoods, especially in Northern forests where cool temperatures slow the decomposition process.

Fig. 2 shows a mor soil with a thick litter (L) layer, slow to decompose, normally found under softwoods whose litter is dry (poor habitat for microorganisms) and has a high cellulose content (slow to decompose). It may accumulate to depths up to18 inches and require fire or mechanical scarification to break it up for regeneration. The F, or fermentation layer, is decomposing litter. Mor soils usually have a sharp delineation between the organic layer and mineral soil and are most common in Northern forests under cool, acid humus conditions with plenty of rainfall—nutrients may dissolve and leach out, creating a grayish layer in the A1 horizon.

Soil-moisture capacity is the key to growth, and available soil water influences the distribution and growth of forest vegetation. Water is a solvent for nutrients and not only affects their amount and distribution but also affects the soil's physical strength, aeration, temperature, microbial activity, and erosion. Forest-soil moisture is rarely "optimal" during the growing season, and the long growing season of the Southeast may be broken by dry conditions in late summer. Soil moisture is classified as follows:

Maximum water-holding capacity—saturated soil condition (after heavy or prolonged rain).

Gravitational water—free to move under gravity, occupies air space after rain but moves out in hours. If retained any length of time—lowlands or swales—it may reduce aeration and injure roots (check for mottling).

Field capacity—water retained after gravitational water drains, usually in one to five days.

Capillary water—water retained against gravity by films in spaces between fine particles (typical of silt/clay). This is related to texture and structure; it may be higher than field capacity but may not all be available to plants.

Hygroscopic water—a thin film of water on soil particles, typical of silts and clays, that is usually not available to plants.

Permanent wilting percentage—wilting point, when leaves first become permanently wilted. This occurs when water absorbed by roots is less than transpiration losses. Most plants respond to dry conditions by slowing down their transpiration losses.

Readily available water—the portion available for growth, above the wilting point, that can be absorbed by tree roots. It is affected by precipitation amount, frequency, season, runoff, storage capacity, and vegetation demands (transpiration). Silvicultural practices such as thinning and burning can be used to increase available water.

Drainage is related to soil structure, texture, and water-holding capacity and is often limited by hardpans and bedrock. It is a measure of the air/moisture content of a soil and its suitability for different species and land uses. Soil scientists use seven drainage classes but four are adequate for our purposes.

Very poorly drained—boggy.

Poorly drained—wet, squishy.

Well-drained—moist, but too dry to form clods.

Excessively well-drained—dry, usually coarser sands and gravels.

Poorly drained soils may change through the growing season, being extremely wet in the rainy portion but turning powder-dry in late August. In such cases, poor drainage can be detected by soil color because intermittent, waterlogged conditions cause mottling—yellow, blue, and green colors—that can be checked with an auger or spade.

Soil nutrient content refers to chemically available elements. Most exist in soil in more than adequate quantities but are "locked up" in chemical combinations not readily useable by plants. Many are tied up in litter and humus and not available until released by fires. Cutting is one means of opening the forest floor to sunlight and warmth to speed litter decomposition. Available nutrients in excess of plant needs are easily lost by leaching in groundwater, a common situation after fire and heavy cutting. Hardwoods usually require more nutrients than softwoods but recycle them annually through leaf fall and decomposition.

Major nutrients and their sources :

C (carbon), H (hydrogen), O (oxygen) and N (nitrogen) in air and water—essential for growth and formation of carbohydrates and plant tissue.

P (phosphorous), K (potassium), Ca (calcium), Mg (magnesium) and S (sulfur)—important, are derived from soil minerals but are often deficient.

Fe (iron), B (boron), Zn (zinc), Cu

(copper), Mn (manganese), Mo (molybdenum), and Cl (chlorine)—less important and sometimes limited in amounts.

Cation exchange capacity (CEC) is the ability of soil to hold and exchange positive ions of plant nutrients—chiefly H, Al, Ca, Mg, K, NH_4 and Na—and is higher in finer-textured soils (clay, humus) and lower in sands. Essential nutrients for tree growth are (macro) N, P, K, Ca, Mg, S and (micro) Fe, Mn, Bo, Cu, Mb, Zn, Cl (trace elements).

N is plentiful in the atmosphere and in soil organic matter but not in forms available to plants. However, bacteria can convert organic N to available forms (NO_3 and NH_4). Nitrogen fixation is the uptake of N gas from the atmosphere by microorganisms in the soil or on plant roots, and mineralization is the decomposition of organic matter in the soil to release useable N. The reverse, denitrification, releases N gas to the atmosphere. This flow of nitrogen through an ecosystem is called the nitrogen cycle.

N, P, and K are the major nutrients needed for growth. Since shortages of N often limit growth, practices to speed its movement into the system can improve growth. Cutting raises soil temperature and moisture content, speeding decomposition of organic matter and raising N availability. But unless there are enough plants to recycle available N, it may leach from the soil in drainage water.

Acidity or alkalinity is expressed as pH on a scale of 1 (most acidic) to 14 (most alkaline) with a midpoint (neutral) of 7. As tree litter is acidic and nutrient uptake by roots removes Ca, Mg, and other elements that form bases, forest soils are normally acidic, ranging from 3.5 to 5.5. This acidity reduces microbial populations and nutrient availability. Farmers raise pH by liming, but this is impractical in the forest: Forest-soil pH may be raised by burning litter and slash. Fertilization may be used to supply missing nutrients but is expensive, and commercial fertilizers, with acid salts, can actually lower pH. Municipal and industrial effluents, papermill sludge, and wood ash from biomass-fired electric plants have been applied to agricultural land in some areas, chiefly as a means of disposal with secondary benefits from improved growth. Some attempts have been made to spread sludge and ash back in the forest.

This ends our very brief consideration of the physical factors—environment and soils—affecting forest sites. In the next issue, we will consider biotic factors affecting the stand, including man. ■

Benjamin Hoffman is a forester with 28 years of experience in state, federal, and private (including two years as a private logging contractor) forestry and 17 years in academia. Ben is semiretired and does part-time consulting. He is a Maine Licensed Forester, and retired as a Vermont Land Surveyor.