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CHAPTER 4

Swamp Earth
Hydric Soils

The combination of landscape position, underlying geology, vegetation, and climate influences the flow of water across and through the land surface. Out of all the factors affecting soil formation, or pedogenesis, water exerts the greatest effect. Differences in the frequency, duration, and seasonality of water flows typically cause a variety of different features to develop in soils of the same parent material. Certain soil properties develop in response to recurrent prolonged wetness, serving as reliable predictors of the long-term hydrology. This makes interpretation of soil morphology vital for wetland identification and delineation, especially in the more problematic situations.

What Is Soil?

In the United States, "soil" is defined by scientists as a collection of natural bodies, made up of mineral and organic materials, that supports or is capable of supporting the growth of land plants "out of doors." The upper limit of soil is air or shallow water. Land plants are self-supporting, free standing plants, such as trees, shrubs, and robust nonwoody species like grasses, sedges, and flowering herbs. Forests, meadows, lawns, and gardens all possess soils. Other unconsolidated materials supporting different plants or lacking vegetation are not soil. Areas vegetated by water lilies, submerged aquatic plants, free-floating species, and algae do not have soils—their supporting medium is a nonsoil called substrate. Other nonsoil areas include glaciers, rock outcrops, salt flats, and barren lands.

Soil is usually made up of a combination of sand, silt, clay, and organic material. Some soils have various amounts of gravel, stones, and rocks. Soils are separated into two general types based on the amount of organic matter in the upper layer: 1) organic soils and 2) mineral soils. Organic soils are dominated by the remains of plants—leaves, stems, twigs, and roots—that accumulate in significant amounts at the soil surface. These soils are commonly called mucks and peats. Mineral soils are mainly composed of mixtures of sand, silt, and clay, often with some enrichment of the surface layer with organic matter. They are further classified by texture based on the relative proportions of sand, silt, and clay (Figure 4.1).

Effects of Waterlogging on Soil Development

Flooding and prolonged waterlogging significantly affect soil characteristics. With few exceptions, soils associated with wetlands possess properties unlike those of dry-land soils. Extended wetness inhibits the natural breakdown of leaves and other plant parts by aerobic bacteria, causing a buildup of organic matter on the soil surface. Shorter periods of wetness are not sufficient to stop oxidation of these materials, but alternate wetting and drying lead to the development of other unique soil properties.

Flooding and soil saturation for long periods (a couple of months or more) during the growing season create long-term anaerobic soil conditions sufficient to prevent aerobic decomposition or oxidation of leaves, stems, roots, and other dead plant parts. Aerobic bacteria that are responsible for the oxidation of these materials cannot survive under such wet conditions, so organic materials accumulate at the surface. This buildup causes the formation of peats and mucks. Over a period of 10,000 years, peat layers 50 feet or more thick develop in some waterlogged depressions, changing lakes to forested wetlands in the process called hydrarch succession (see Chapter 3).

Where soils are not sufficiently wet to promote this organic accumulation, mineral soils typically develop. They exhibit a wide range of

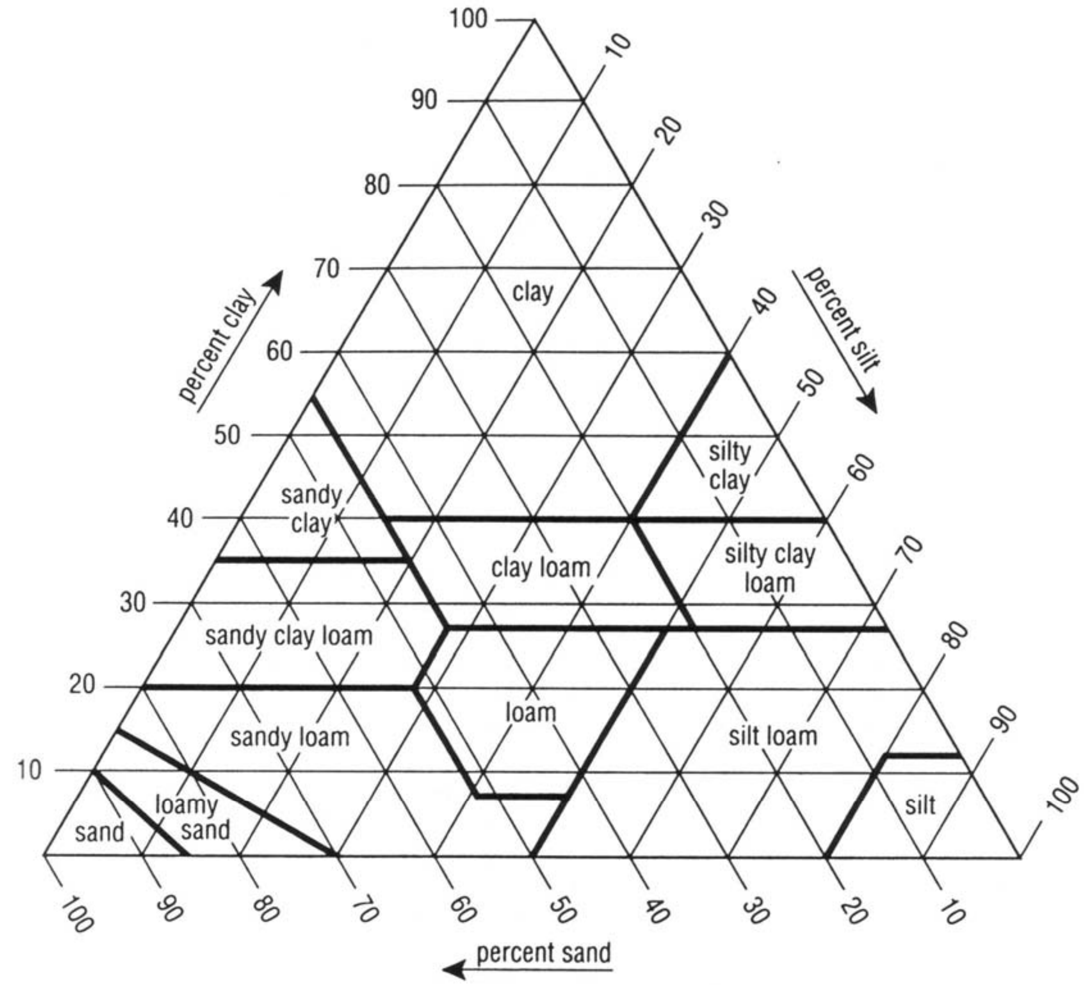

Figure 4.1. Soil textures are the result of different combinations of sand, silt, and clay particles, as illustrated by the textural triangle. (Source: Soil Survey Division Staff 1993)

properties related to differences in parent material, climate, topography, age, and other factors. Changes in the frequency, duration, and depth of saturation produce soil characteristics that help separate wetlands from uplands. Wetter mineral soils subject to significant flooding often develop thick organic surface layers (up to 16 inches thick). Most mineral soils are not wet enough for these layers to develop. Instead, organic matter enriches the surface layer but does not accumulate as a peat or muck layer. This often produces a very dark brown to blackish surface layer in wetland soils. Below the topsoil, the subsoil is typically grayish (see Chapter 10).

Inundation of a soil effectively eliminates gas exchange between the atmosphere and the soil. Existing oxygen in soil pores is quickly consumed by soil microbes, creating anaerobic conditions. Some gas exchange still occurs at the soil-water surface, but the little gas exchange between water in the pores and the soil is extremely slow—ten thousand times slower than gas exchange from air-filled pores to the soil. Anaerobic conditions can develop within one day in some soils and within a few days in most soils. Temperature affects the rate at which such conditions become established: the colder the temperature, the slower the rate. Soil scientists have long considered 41° F measured at a depth of 20 inches to be "biological zero," the temperature at which biological activity in the soil ceases. Recent studies in Alaska have found that permafrost soils never get above this temperature at that depth, yet hydric soils still develop above permafrost when saturated for prolonged periods. Microbial activity has also been detected in these soils and at lower temperatures. Thus the concept of biological zero needs revision since it is likely that soil is biologically active to some degree whenever it is not frozen.

Anaerobic bacteria are important agents in the formation of soil properties associated with wetlands. These microbes are well adapted to the low oxygen conditions resulting from sustained wetness. They derive their energy from the oxidation of organic matter. A series of biochemical events called the oxidation-reduction (redox) process takes place in flooded or saturated soils. In a flooded soil, the oxygen that was present prior to flooding is consumed by microbes in a couple of days provided there is organic matter present for them to digest. When dissolved oxygen is removed, the soil becomes chemically reduced. This means that various elements will become more soluble in sequence, beginning with nitrate. After converting nitrate to free nitrogen in a process called "denitrification" (an important part of the water-quality renovation provided by wetlands), selected microbes reduce manganese from the manganic (oxidized) to the manganous form. Iron is the next element to be reduced from ferric iron (oxidized) to ferrous iron. The process continues with microbes reducing the sulfates and carbon and producing respectively hydrogen sulfide (giving the smell of rotten eggs) and methane (odorless) as by-products. Reduced compounds are often soluble in water and available for plant uptake. These and other mobilized elements (e.g., aluminum) are toxic to most plants in large quantities, so they limit the types of plants that can live in wetlands. The reduction process, therefore, has a profound effect on plant composition as well as on soil chemistry and morphology.

Morphological properties called "redoximorphic features" indicate varying amounts of soil wetness. The biochemical processes causing iron and manganese reduction have a great effect on soil color and morphology. Iron is typically the most abundant element in the soil. In its oxidized (ferric) state, iron gives well-drained soils their characteristic yellowish, reddish, orangish, or brownish colors. When iron is reduced (ferrous), it is soluble and usually moves within or out of the soil, leaving sandy soils grayish and finer-grained soils bluish, grayish, or greenish (gleyed). These colors are considered "redox depletions" since they are caused by iron depletion; the process is called "gleization." Gray reflects the natural color of soil particles (sand, silt, and clay), while blue usually indicates the presence of ferrous iron. If the soil conditions are such that free oxygen is present, organic matter is absent, or temperatures are below freezing and thus too low to sustain microbial activity, gleization will not begin and redox depletions (gleyed colors) will not appear, even though the soil may be saturated for long periods. Soils saturated only during the coldest part of winter do not develop gleyed colors.

Redox depletions may also occur in clay through similar processes. Clay depletions appear as gray coatings on either channels through or the outer surface of natural soil macroparticles (peds). The adjacent soil matrix and the underlying soil layers will have a higher clay content, and so clay coatings can be found on outer layers of peds.

Mineral soils that are wet for most of the year usually have reduced colors dominating the subsoil layer immediately below the surface layer and often within one foot of the surface. Soils exposed to shorter periods of wetness are variously colored. The wetter ones are grayish, with spots or blotches of yellow, orange, or reddish brown (high-chroma mottles). These brighter colors represent concentrations of iron oxides—"redox concentrations"—and a fluctuating water table. Many times, they develop along channels in wet soils where plant roots are leaking oxygen and soluble iron has combined with the oxygen to form ferric iron. These orangish coated channels, called "oxidized pore linings" or "oxidized rhizospheres," are evidence of a plant living under anaerobic conditions. Drier soils subjected to brief periods of wetness are brighter colored overall (red, yellow, brown, or orange) with grayish mottles (low chroma mottles). Soils with short-term wetness may have only high-chroma mottles, while soils lacking significant wetness typically are not mottled. Chapter 10 tells how to recognize hydric soils.

What Is Hydric Soil?

Over time, several terms have been used to describe wetland soils. In characterizing soils for agricultural uses, scientists have divided them into seven drainage classes: (1) excessively drained, (2) somewhat excessively drained, (3) well drained, (4) moderately well drained, (5) somewhat poorly drained, (6) poorly

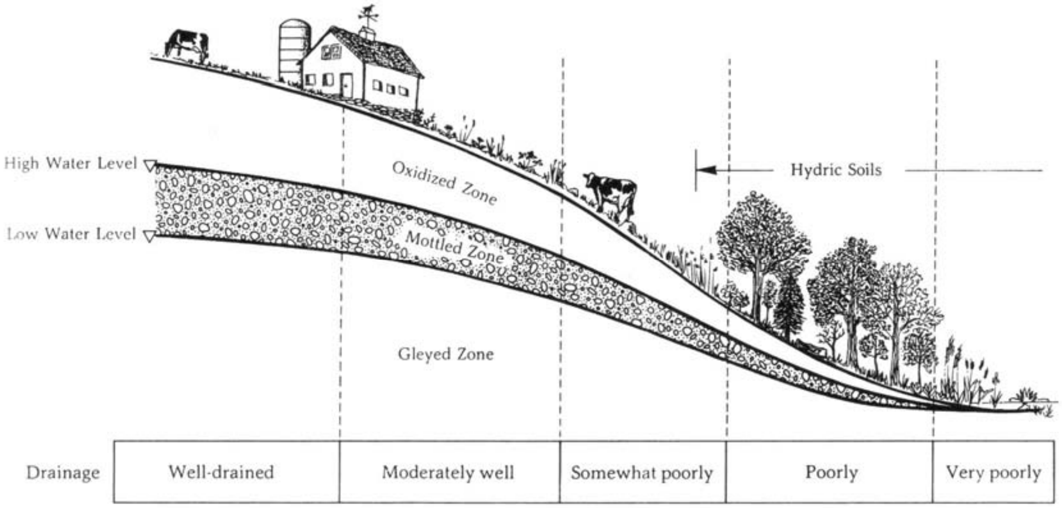

Figure 4.2. The position of the seasonal high water table relative to the land surface is strongly influenced by slopes. Hydric soils typically develop in depressions or at the bottom of slopes. These soils also form on steeper slopes in areas of heavy groundwater discharge, along drainageways, or in depressions on the slopes. Very poorly drained soils typically occur in depressions that are inundated for much of the growing season. Poorly drained soils are flooded for shorter periods or saturated for extended periods. (Source: Tiner and Veneman 1995)

drained, and (7) very poorly drained. The latter two types are characteristic of wetlands. Poorly drained soils remain waterlogged at or near the surface long enough during the growing season that most crops cannot be grown unless the land is artificially drained. Very poorly drained soils are saturated for extended periods, are frequently inundated, and have the same limitation for crop production. Under natural conditions, both of these soil types typically support the growth of hydrophytes (wetland vegetation). The other drainage classes are too dry to produce wetlands, with two exceptions: 1) better-drained soils that are frequently flooded for long periods and 2) somewhat poorly drained soils in lower landscape positions that occasionally are wet enough to become wetlands (Figure 4.2). The latter soils are typically wet only for short periods, usually early in the growing season. It is important to recognize that these drainage classes were not developed for wetland determinations; rather, they were created to separate different soils into groups for agriculture. Moreover, the terms have been interpreted locally, so what one state or county considers to be somewhat poorly drained may be poorly drained from another state's or county's view. This has caused some confusion in their use for wetland identification.

Wetland soils have also been called "hydromorphic," "halomorphic," and "alluvial." The first term includes waterlogged soils associated with marshes, swamps, and bogs: peats, mucks, and gleyed soils. The third term includes frequently inundated floodplain soils, whereas the second term is applied to the wet soils of coastal salt marshes and inland alkaline wetlands (arid regions in the West).

Wetland soils are now called "hydric." The term was coined as part of the national wetland classification system developed by the U.S. Fish and Wildlife Service (FWS) in the late 1970s (see Chapter 1). The "predominance of undrained hydric soils" is one of the indicators for identifying wetlands. During the past twenty years, the Department of Agriculture's National Technical Committee for Hydric Soils has worked to refine the term and maintain county, state, and national lists of hydric soils (Chapter 10). The latest technical criteria for defining hydric soils are listed below.

1995 technical criteria for hydric soils. Aquic soils are saturated and reduced for a significant period during the growing season, which is defined by soil temperature ("biologic zero" ≥41° F measured at 20 inches below the surface); the water-table depths in the criteria identify those soils with water tables at or near the surface. Ponding is surface water derived from high water tables and runoff from adjacent uplands, while flooding involves overbank inundation from high river flows. Long and very long duration are greater than one week and greater than one month, respectively. "Frequently," in terms of inundation, means occurring more than fifty times in 100 years.

1. All histosols except folists, or
2. Soils in aquic suborders, great groups, or subgroups, albolls suborder, aquisalids, pachic subgroups, or cumulic subgroups that are:
   a. somewhat poorly drained, with a water table equal to 0.0 foot from the surface during the growing season, or
   b. poorly drained or very poorly drained, and have either:
      (1) water table equal to 0.0 foot during the growing season if textures are coarse sand, sand, or fine sand in all layers within 20 inches, or for other soils:
      (2) water table less than or equal to 0.5 foot from the surface during the growing season, if permeability is equal to or greater than 6.0 inches/hour in all layers within 20 inches, or
      (3) water table less than or equal to 1.0 foot from the surface during the growing season, if permeability is equal to or greater than 6.0 inches/hour in any layer within 20 inches, or
3. Soils that are frequently ponded for long or very long duration during the growing season, or
4. Soils that are frequently flooded for long or very long duration during the growing season.

Hydric soil is now defined as "soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part." This means simply that wetness is of sufficient duration for the soil to lose oxygen long enough for the growth of most plants to be curtailed in favor of hydrophytes (Chapter 5). Some hydric soils are submerged for the greater part of the year, while those intergrading toward better-drained upland soils are wet for shorter periods and dry at the surface for much of the growing season. Hydric soils typically consist of very poorly drained and poorly drained soils having a water table within a foot of the surface for two weeks or more during the growing season. Very poorly drained soils are flooded for much of the year or permanently saturated. Poorly drained soils are usually saturated to the surface at some time during the year, especially winter in the Northeast. Hydric soils also include soils ponded or frequently flooded for seven or more consecutive days during the growing season.

Many hydric soils are drained by open ditches, tiles, or combinations of dikes, ditches, and pumps. Water is also diverted from wetlands through other means, such as by government-financed channelization projects, upstream dams, or groundwater extraction (e.g., municipal or industrial well fields). Soils that were formerly wet but are now effectively drained, no longer having wetland hydrology and therefore not providing wetland functions, are among the most difficult in which to make wetland determinations, usually requiring measurement of the current hydrology. Where drainage fails, such soils usually revert to hydric conditions and return to wetland. This simple fact makes wetland restoration of these sites feasible and cost effective.

Key points to remember are that 1) soil classified as hydric must be saturated or flooded long enough during the growing season to produce the low oxygen conditions that damage most plants but favor hydrophytes; 2) soil that is well drained but frequently flooded or saturated for short periods of time is not hydric; and 3) soil that was formerly wet but is now effectively drained is considered drained hydric soil, and the area is not considered wetland.

Additional Readings

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