Soil Formation in the Unglaciated Northern Plains

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Soil is the medium in which grassland plants grow. Major variations in soil properties result from differences in the type of parent material and in the soil developmental processes. Plant community dynamics and plant growth potentials are affected by the changing characteristics occurring during the continuous progression of soil formation, and soil, climate, and plants have complex cause-effect relationships regulating soil formation. Management practices affect these relationships and can enhance or impair soil developmental processes.

Parent Material from Sedimentary Deposits

The unglaciated region of the Northern Plains is part of a large geologic depression, which has been filled over a period of 515 million years with accumulations of sedimentary rocks deposited in off-shore shallow seas and in near-shore marine environments or by running water on floodplains or deltas. For about the last 5 million years, running water and wind have been eroding the generally flat-lying sedimentary deposits in the unglaciated region. These erosional forces have been selective in their action because hard, relatively resistant sandstone, limestone, scoria, chert, or other erosion-resistant materials were present in some of the sedimentary deposits and have remained as protective caps, while the soft, weakly consolidated, less resistant silt and clay layers have been easily washed or blown away. The landforms that have resulted from uneven sediment removal are gently rolling to hilly plains intermingled with buttes, which have flat tops and steep slopes. Over the last 600,000 years, badlands topography has developed near some streams and rivers from erosional forces that accelerated sediment removal when glacial ice blocked the northward flow of the drainage systems. The diverted routes to the east were shorter and steeper, and the water flowing in the drainage systems caused deep, rapid erosion that resulted in badlands landforms (Hunt 1974, Bluemle 1977, Trimble 1990, Bluemle 1991, Bluemle 2000).

Soil Development from Sedimentary Deposits

Soils in the unglaciated region have been developing from weathered sedimentary deposits of soft shale, siltstone, and sandstone. Soil formation is a long, slow, continuous process. Temperatures and precipitation levels of the area have been important in the development of the regional soils. The climate has determined the type of vegetation and the amount of annual growth, which, in turn, have influenced the amount of soil organic matter accumulated.

Temperature affects the rate of oxidation of organic matter. Higher temperatures promote rapid oxidation of organic matter, and soils in regions with long periods of high temperatures contain little organic matter. Little or no oxidation of organic matter occurs in frozen soil. Organic matter has accumulated in the soils in the Northern Plains because the climate has cold periods during which little chemical activity takes place. In most years, soils in the unglaciated region have frost penetration to a depth of 3 to 5 feet for a period of approximately 120 days (Larson et al. 1968), a condition that contributes to soil organic matter accumulation. The dark surface layer of most soils in the region has an accumulation of 2 to 5% organic matter (Larson et al. 1968, Wright et al. 1982).

Temperature and precipitation have influenced the amount and kinds of physical and chemical weathering of the region's parent material. High temperatures and high precipitation have encouraged rapid weathering and clay formation during the summer, while low temperatures during fall, winter, and early spring have caused cracks, fissures, and breaks in the parent material and developing soil as a result of the expansion and contraction forces of frost.

Precipitation level has influenced the amount of water in the soil. The amount of water that has entered the soil has not been the same as the precipitation level, and the amount of soil water has not been the same on all parts of the landscape. The amount of soil water has been less than the amount of precipitation received in areas that have had rain run off, and the amount of soil water has been greater than the amount of precipitation received in areas that have had rain run in. The amount of soil water present has affected the rate of leaching. The depth of the downward movement of the water has not been uniform for the soils on different topographic positions on the landscape.

Soil water has dissolved calcium carbonate (lime), soluble salts, exchangeable sodium, and clay particles from the upper horizons of the soil and moved them downward into a lower horizon. The amount of these dissolved materials in the soil profile has been dependent on the amount present in the weathered parent material. The depth to which they have been moved has varied with the amount of soil water. The layer where the dissolved material has accumulated indicates the approximate average depth of downward water movement. The depth of the accumulation layer decreases when the precipitation decreases. Soils with a high lime content have developed a layer of natural cement (hardpan) that restricts plant root penetration. Soils high in soluble salts and/or exchangeable sodium have developed accumulation layers containing sufficient amounts of these chemicals to impair plant growth. Soils high in soluble salts have developed into saline soils; soils high in exchangeable sodium have developed into sodic soils; and soils high in both have developed into saline-sodic soils (Omodt et al. 1968, Soil Survey Staff 1975, Foth 1978).

Soil water has also dissolved clay particles and moved the clay downward. When the soil water with dissolved clay has hit areas of dry soil, the water has been withdrawn and the clay particles have been deposited. Over time this clay film layer has built up to form what is called an argillac horizon. Low amounts of argillac horizon in a soil can be beneficial because the clay helps increase the amount of water and nutrients stored in that zone; however, when the clay accumulation becomes great, the effects can be detrimental because water movement and plant root penetration are severely restricted. Soils that have a well-developed argillac horizon are called clay-pan soils (Omodt et al. 1968, Soil Survey Staff 1975, Foth 1978).

The depth of the layer where the dissolved material accumulates is very important because it determines the thickness of the plant growth medium; the soil above the layer of accumulation holds the nutrients and soil water needed to sustain plant life. Shallow soils restrict plant growth. The depth of the accumulation layer decreases westward with the reduction in precipitation and ranges from 6 inches to 4 feet. Most soils in western North Dakota have formed the accumulation layer between 15 and 24 inches below the soil surface (Larson et al. 1968, Omodt et al. 1968, Soil Survey Staff 1975, Foth 1978, Wright et al. 1982).

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