Rangeland Soil Quality

National Park Service
U.S. Department of the Interior

Inventory & Monitoring Program
Soil Resources Inventory

Infiltration

The process of water soaking into the soil is infiltration. "Infiltration rate" is simply how fast water enters the soil and is usually measured in inches or millimeters per hour. This rate depends on soil texture (amount of sand, silt, and clay) and on soil structure. Soils in good condition have well developed structure and continuous pores to the surface. As a result, water from rainfall or snowmelt readily enters these soils.

Why is infiltration important?

Soil is a reservoir that stores water for plant growth. The water in soil is replenished by infiltration. The infiltration rate can be restricted by poor management. Under these conditions, the water does not readily enter the soil and it moves downslope as runoff or ponds on the surface, where it evaporates. Thus, less water is stored in the soil for plant growth, and plant production decreases, resulting in less organic matter in the soil and weakened soil structure that can further decrease the infiltration rate. Runoff can cause soil erosion and the formation of gullies. It also carries nutrients and organic matter, which, together with sediment, reduce water quality in streams, rivers, and lakes. The sediment reduces the capacity of reservoirs to store water. Excessive runoff can cause flooding, erode streambanks, and damage roads. Runoff from adjacent slopes can saturate soils in low areas or can create ponded areas, thus killing upland plants. Evaporation in the ponded areas reduces the amount of water available to plants.

Why is infiltration important?

The proportion of water from rainfall or snow-melt that enters the soil depends on "residence time" (how long the water remains on the surface before running off) and the infiltration rate. These are affected by vegetation and many soil properties.

Residence time- The length of time that water remains on the surface depends on the slope, the roughness of the soil surface, and obstructions to overland flow, such as plant bases and litter. Consequently, plant communities with large amounts of basal area cover, such as grasslands, tend to slow runoff more than communities with small amounts of basal cover, such as shrub lands.

Infiltration rate- The infiltration rate is generally highest when the soil is dry. As the soil becomes wet, the infiltration rate slows to the rate at which water moves through the most restrictive layer, such as a compacted layer or a layer of dense clay. Infiltration rates decline as water temperature approaches freezing. Little or no water penetrates the surface of frozen or saturated soils.

Vegetation- A high percentage of plant cover and large amounts of root biomass generally increase the infiltration rate. Different plant species have different effects on infiltration. The species that form a dense root mat can reduce the infiltration rate. In areas of arid and semiarid rangeland, the infiltration- limiting layer commonly is confined to the top few millimeters of the soil, particularly in the open spaces between plant canopies. These areas receive few inputs of organic matter, which build soil structure. Also, the impact of raindrops in these areas can degrade soil structure and form physical crusts.

Soil Properties

The properties that affect infiltration and cannot be readily changed by management include:

Texture.—Water moves more quickly through the large pores and spaces in a sandy soil than it does through the small pores in a clayey soil. Where the content of organic matter is low, texture plays a significant role in the susceptibility of the soil to physical crusting.

Clay mineralogy.—Some types of clay develop cracks as they dry. These cracks rapidly conduct water to the subsurface and seal shut once the soil is wet.

Minerals in the soil.—High concentrations of sodium tend to inhibit the development of good structure and promote the formation of surface crusts, which reduce the infiltration rate. Calcium improves soil structure.

Soil layers.—Subsurface soil, including a subsoil of dense clay, cemented layers, and highly contrasting layers, such as coarse sand over loam, can slow water movement through soil and thus limit infiltration.

Depth.—Soil depth controls how much water the soil can hold. When soil above an impermeable layer, such as bedrock, becomes saturated, infiltration ceases and runoff increases. The properties that affect infiltration and can be readily changed by management or a shift in vegetation are:

Organic matter and soil biota.—Increased plant material, dead or alive, generally improves infiltration. As organic matter is broken down by soil organisms, it binds soil particles into stable aggregates that enhance pore space and infiltration.

Aggregation and structure.—Good soil structure improves infiltration. Soils with good structure have more pores for the movement of water than soils with poor structure. If aggregates are stable, the structure remains intact throughout a rainstorm.

Physical crusts.—Physical crusts form when poorly aggregated soils are subject to the impact of raindrops and/or to ponding. Particles broken from weak aggregates can clog pores and seal the surface, thus limiting water infiltration.

Biological crusts.—Biological crusts can either increase or reduce the infiltration rate. Their effect on the infiltration rate depends on many other factors, including soil texture.

Pores and channels.—Continuous pores connected to the surface convey water. Such organisms as earthworms, ants, and termites increase the number of pores. Termites, however, can decrease the infiltration rate by reducing the amount of litter cover, and some ant species seal the surface around their nests.

Soil density.—A compacted zone close to the surface restricts the entry of water into the soil and often results in surface ponding. Increased bulk density reduces pore space and thus the amount of water available for plant growth.

Water- repellent layer.—As shrubs and an underlying thick layer of litter burn in a hot fire, very high temperatures can occur directly beneath the shrubs. The heat forces a gas from the burning plant material into the soil. When it cools, the gas forms a water- repellent layer that limits infiltration. This feature is temporary, although it may persist for a number of years. Some soils can be slightly water repellent when dry.

Management Strategies

Assessment estimates or measures the functional status of ecological processes. The assessment must start with an understanding of the standard to be used for comparison. For assessments of rangeland, the ecological site description is used as a standard at the site scale. Information from the ecological site description should be supplemented, if possible, with data from local reference sites. The optimum time and location for making assessments depend on the objectives. Potential objectives include:

- selection of sites for monitoring,
- gathering of inventory data used in making decisions,
- identification of areas at risk of degradation, and
- targeting of management inputs.

The timing of assessments also depends on seasonal cycles. Some soil properties are highly variable on a daily, seasonal, or yearly basis in response to changes in both temperature and moisture. For example, the total amount of organic matter in a soil is relatively insensitive to seasonal changes, whereas rills can become less apparent, depending on the length of time and conditions since the most recent major storm. Careful site selection helps to ensure that the assessment sites are truly representative of the area of interest. The sites should be on the same soil and in the same landscape position as the area they represent. Offsite features, such as roads, homesteads, and other areas of recent or historic disturbances, can have significant impacts and should either be avoided or noted. The management history of the site can aid in interpretation.

For More Information

Pete Biggam
Soils Program Coordinator
303- 987- 6948
pete_biggam@nps.gov

More information can also be found on the Soils website at: www2.nature.nps.gov/geology/soils

The National Park Service, Soil Inventory and Monitoring Program is partnering with the USDA-Natural Resources Conservation Service, and the USDA Agricultural Research Service, Jornada Experimental Range, to develop a series of assessment and monitoring protocols to assist NPS Vital Signs Monitoring Networks in understanding and evaluating the important role soils play within ecosystems.