United States Department of Agriculture
Natural Resources Conservation Service

Rangeland Soil Quality
Infiltration

Double ring infiltrometer

What is infiltration?

Infiltration is the process of water moving downward from the soil surface into the soil profile. "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), moisture content and soil structure. Soils with well developed structure and continuous pores to the surface allow water to readily enter the soil profile.

Why is infiltration important?

Soil is a reservoir that stores water for plant growth. The water in soil is replenished by infiltration which can be restricted as a result of improper management. Improper rangeland management impedes vertical water movement by reducing pore space and size and results in either downslope runoff or ponding on upland soils where it is lost to evaporation. When less water is stored in the soil for plant growth, plant production decreases, resulting in less organic matter additions to the soil. This weakens soil structure, further decreasing the infiltration rate.

Runoff can cause soil erosion and the formation of rills and/or gullies when flow becomes concentrated. It also carries nutrients and organic matter, which, together with sediment, reduce water quality in streams, rivers, and lakes. 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 in upland soils that normally do not pond, thus killing upland plants. Evaporation in the ponded areas reduces the amount of water available to plants.

What factors affect infiltration?

The proportion of water from rainfall or snowmelt that enters the soil depends on the "residence time". (how long the water remains on the surface before running off) and the infiltration rate. These are affected by vegetation and select 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 limiting layer. This limiting layer has the least amount and percentage of large pores compared to small soil pores 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 diversified native plant community with a high percentage of plant cover, varying rooting depths and structure, and large amounts of root biomass generally increase infiltration rates. Different plant species have different effects on infiltration. Species that form a dense root mat (e.g. Kentucky bluegrass or blue grama) 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 and porosity.

The accumulation of a thatch layer (intermingled organic layer of dead and living roots, stems, stolons, rhizomes and shoots that develops between the soil surface and the zone of green vegetation) due to

Kentucky bluegrass invasion will also decrease initial infiltration rates.

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.

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 shrink and develop cracks as they dry. These cracks rapidly conduct water to the subsurface and, as the soil moistens, the clay swells and the cracks seal shut, limiting further rapid water infiltration.

Minerals in the soil.—High concentrations of sodium tend to inhibit the development of good structure and promote the formation of surface crusts and dense sodic subsoil clay layers, which reduce the infiltration rate.

Soil layers.—Subsurface soil, including a subsoil of 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, the organic matter and substances the organisms produce bind soil particles into stable aggregates which enhance pore space and infiltration.

Aggregation and structure.—Highly aggregated soils have more pore spaces which allow for the movement of water into and within the soil. Soil structure affects water and air movement within the soil which influences the soil's ability to perform vital functions.

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 close pores and seal the surface, thus limiting water infiltration.

Pores and channels.—Continuous pores connected to the surface convey water. Large-sized soil organisms help increase the number of pores. Earthworms commonly fill this role on well managed cropland and although occasionally observed, are not a native component of the rangeland soil biota in North Dakota.

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

Water-repellent layer.—Some soils can be slightly water repellent when dry.

Management strategies

The soil and vegetation properties that currently limit infiltration and the potential for increasing the infiltration rate must be considered in any management plan. Where waterflow patterns have been altered by a shift in vegetation, such as a shift from grassland to open-canopy shrub land, restoration of higher infiltration rates may be difficult or take a long period, especially if depletion of organic matter and/or soil loss have occurred. Excessive grazing of forage can impair infiltration. Management strategies include:

- Increase the amount of plant cover, especially of plants that have positive effects on infiltration such as deep rooted native bunchgrasses like green needlegrass.
- Decrease the extent of compaction by avoiding the use of machinery and concentrated animal impact when soils are wet.
- Decrease the formation of physical crusts by maintaining or improving the cover of plants or litter and thus reducing the impact of raindrops.
- Increase aggregate stability by increasing the amount of organic matter added to the soil through residue decomposition and vigorous root growth which encourages formation of glue-like substances. from biological activity.

For more information, check the following: http://soils.usda.gov/sqi and http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/ (Adapted from Rangeland Sheet #5, May 2001, developed by the Soil Quality Institute, Grazing Lands Technology Institute, and National Soil Survey Center, Natural Resources Conservation Service, USDA; the Jornada Experimental Range, Agricultural Research Service, USDA; and Bureau of Land Management, USDI)

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