soil Infiltration

Soil Quality Kit – Guides for Educators

United States Department of Agriculture
Natural Resources Conservation Service

Soil infiltration refers to the soil's ability to allow water movement into and through the soil profile. It allows the soil to temporarily store water, making it available for uptake by plants and soil organisms. Infiltration rates are a measure of how fast water enters the soil and are typically expressed in inches per hour. For initial in-field assessments, however, it is more practical to express infiltration time in the number of minutes it takes soil to absorb each inch of water applied to the soil surface. Water entering too slowly may lead to ponding on level fields, erosion from surface runoff on sloping fields, or inadequate moisture for crop production. An adequate amount of water must infiltrate the soil profile for optimum crop production. Porous soils allow water to infiltrate and recharge ground-water aquifers and sustain base flow in streams. An infiltration rate that is too high can lead to nitrate-nitrogen or pesticide leaching, if they are not managed correctly. Management measures, such as residue management, cover crops can improve infiltration.

Inherent Factors Affecting Soil Infiltration

Inherent factors affecting soil infiltration, such as soil texture, cannot be changed. Soil texture (percentage of sand, silt, and clay) is the major inherent factor affecting infiltration. Water moves more quickly through large pores of sandy soil than it does through small pores of clayey soil, especially if clay is compacted and has little or no structure or aggregation.

Depending on the amount and type of clay minerals, some clayey soils develop shrinkage cracks as they dry. The cracks are direct conduits for water entering the soil, causing clayey soils to have high infiltration rates under dry conditions. Where cracks do not occur, clayey soils have slow infiltration rates.

Infiltration Management

Management practices (such as providing ground cover and managing equipment traffic to avoid compaction) impact infiltration by affecting surface crusting, compaction, and soil organic matter. Without a protective vegetative or residue cover, bare soil is subject to direct impact and erosive forces of raindrops that dislodge soil particles. Dislodged soil particles fill in and block surface pores, contributing to the development of surface crusts which restrict water movement into the soil. Compaction can result from equipment traffic, especially on wet soils, and tillage pans. Compacted or impervious soil layers have less pore space and restrict water movement through the soil profile.

As soil moisture levels increase, infiltration rates decrease. Soil moisture is impacted by water uptake by plants, residue and vegetative cover, irrigation practices, and drainage measures. Dry soils tend to have pores and cracks that allow water to enter faster than wet soils. As soils become wet, infiltration rate slows to a steady rate based on how fast water can move through the most restrictive layer, such as a compacted layer, or a layer of dense clay.

Soil organic matter binds soil particles together in stable aggregates, increasing porosity and infiltration. Soils with a high content of organic matter also provide good habitat for soil biota, such as earthworms. Soil biota increase pore space and create continuous pores linking surface soil layers to subsurface soil layers.

Long-term solutions for maintaining or improving soil infiltration include practices that increase organic matter content and aggregation and minimize runoff, soil disturbance, and compaction. Increases in organic matter content result in increased aggregation and improved soil structure, which lead to improved infiltration rates.

Measures that can improve infiltration rates:

- Avoiding soil disturbance and equipment operation when soils are wet
- Using designated field roads or rows for equipment traffic
- Reducing the number of trips across the field
- Subsoiling to break up existing compacted layers
- Using continuous no-till
- Adding solid manure or other organic materials
- Using rotations with high-residue crops, such as corn and small grain, and perennial crops, such as grass or alfalfa
- Planting cover crops and green manure crops
- Farming on the contour
- Establishing terraces or other runoff- and erosion-control structures

Problems Related to Infiltration and Relationship of Infiltration to Soil Function

When rainfall occurs at a rate that exceeds the soil's infiltration capacity, runoff moves downslope or ponds on the surface of level land. When runoff occurs on bare or poorly vegetated soil, erosion occurs. Runoff carries away nutrients, chemicals, and soil, resulting in decreased soil productivity, offsite sedimentation of water bodies, and diminished water quality. Tables 1 and 2 show, for periods of 1 year to 100 years, rainfall frequencies, duration of rainfall events, and inches of rainfall.

Table 1. Rainfall intensity and duration patterns for Mead, NE.*

Frequency	**Duration of Rainfall Event (inches of rain)**		
	30 minutes	1 hour	2 hours
1 year	1.2	1.1	1.8
2 years	1.3	1.7	1.9
5 years	1.7	2.1	2.4
10 years	2.0	2.5	2.8
100 years	2.8	3.7	4.2

* D.M. Herschfield, *Rainfall Frequency Atlas of the U.S.*, U.S. Weather Bureau, 1961.

Table 2. Rainfall intensity and duration patterns for North Platte, NE.*

Frequency	Duration of Rainfall Event (inches of rain)		
	30 minutes	1 hour	2 hours
1 year	0.9	1.1	1.2
2 years	1.1	1.4	1.5
5 years	1.5	1.9	2.1
10 years	1.8	2.2	2.5
100 years	2.6	3.4	3.7

* D.M. Herschfield, *Rainfall Frequency Atlas of the U.S.*, U.S. Weather Bureau, 1961.

Restricted infiltration and ponding result in poor soil aeration. This leads to poor root function, poor plant growth, reduced availability of nutrients to plants, and reduced cycling of nutrients by soil organisms.

Infiltration rate is most affected by conditions near the soil surface and can change drastically according to management. Infiltration is rapid through large continuous pores at the soil surface and slows as pores become smaller. Steady-state infiltration rates typically occur when soil is nearly saturated and are listed for varying textural classes in Table 3. These are average values and should not be generalized for all soil types.

Table 3. Steady infiltration rates for general soil texture groups in a very deeply wetted soil (Hillel, 1982). (Only use these values to compare infiltration rates to the second inch of water.)

Soil Type	Steady infiltration rate (inches per hour)
Sands	> 0.8
Sandy and silty soils	0.4 - 0.8
Loams	0.2 - 0.4
Clayey soils	0.04 - 0.2
Sodic clayey soils	< 0.04

What measures are being used that impact infiltration rates? ______________________________________

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Do they increase or decrease infiltration rates? (Why or why not?)

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Measuring Infiltration

Materials Needed to Measure Infiltration

____ 3-inch-diameter ring

____ Plastic wrap

____ Plastic bottle marked at 107 mL (for 1 inch of water) or graduated cylinder

____ Distilled water or rainwater

____ Stopwatch or timer

Considerations – Select a representative test location. For comparison, select a location under different management. For example, select a wheel traffic row and a row without wheel traffic. Ideally, bulk density of each location is known.

A single ring measurement is only an estimate, so it is recommended that multiple be tested.

The test should not be conducted when the surface soil is unusually dry. If necessary, add water and allow enough time to soak in prior to conducting the test. You can also choose to conduct the test after rain or irrigation.

Infiltration Test

1. Clear all residue from the soil surface. Drive the ring to a depth of 3 inches using a small sledge and plastic impact driver or block of wood. Gently firm the soil around the inside of the ring to avoid any gaps.
2. Line the ring with plastic wrap so that it covers the inside of ring and drapes over the side.
3. Pour 107 mL of distilled water or rainwater into plastic-lined ring (Figure 1).

Figure 1. Water is poured into plastic-lined ring.

4. Gently pull plastic wrap away. Record the time it takes for water to infiltrate soil. Stop time is when the soil is “glistening.”
5. Repeat steps 2, 3, and 4 with another inch of water to estimate steady-state infiltration.
6. Record the results in Table 4.
7. The ring can be removed with soil intact for use indoors in the respiration test and/or bulk density test.

Interpretations

Record first inch, and second inch (steady-state) infiltration rates and associated information by completing Table 4 and answering discussion questions. Infiltration rate reflects the *maximum rate before runoff or ponding will occur*. Compare infiltration rates for different fields, soil types, and management systems. In some cases it may take three or more inches to reach a steady state infiltration rate.

Table 4. Infiltration data sheet.

Location	Soil Texture	First Inch of Water		First Infiltration Time (minutes)	Infiltration Rate (inches/hr)	Second Inch of Water		Date: May 1, 2012	
		Start Time	End Time			Start Time	End Time	Second Infiltration Time (minutes)	Steady State (inches/ hr)
Wheel track	Silty clay loam	2:00	5:00	180	0.33	5:00	8:20	200	0.30
Non-wheel track	Silty clay loam	2:00	2:01	1	NA	2:02	4:02	120	0.5
Notes:									

Did the rate change from the first to the second inch? Why or why not? Would you expect a steady-state infiltration rate if a third inch of water is added?

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How does your infiltration time compare to the expected frequency and duration of a 1-inch rainfall in Tables 1 and 2 or rainfall events you might expect in your area? Do you expect runoff to occur?

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How do your infiltration rates compare to the steady-state infiltration rates in Table 3? Are rates higher, lower, or similar to the same soil type? Why or why not?

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Glossary

Infiltration Rate – A measure of how fast water enters the soil, typically expressed in inches per hour but recorded in minutes for each inch of water applied to the soil surface.

Restrictive Layers – Compacted layers and layers of dense clay, bedrock, or other restrictive features than limit infiltration below the surface of the soil.

Soil Aggregates – Soil particles held together by organic matter and related substances. Well aggregated soils have higher infiltration rates and are less prone to erosion.

Soil Porosity – Amount of pore space in the soil. Soils with higher porosity have more pore space and higher infiltration rates than those with lower porosity.

Steady-State Infiltration – The infiltration rate is steady and does not increase or decrease as more water is added. It typically occurs when the soil is nearly saturated.