soil Infiltration

Soil Health – Guides for Educators

USDA NRCS
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Soil infiltration refers to the ability of the soil to allow water to move into and through the soil profile. Infiltration allows the soil to temporarily store water, making it available for use by plants and soil organisms. The infiltration rate is a measure of how fast water enters the soil, typically expressed in inches per hour. For initial in-field assessments; however, it is more practical to express the infiltration rate as the minutes needed for a soil to absorb each inch of water applied to the surface. If the rate is too slow, it can result in ponding in level areas, surface runoff, and erosion in sloping areas and can lead to flooding or inadequate moisture for crop production. Sufficient water must infiltrate the soil profile for optimum crop production. Water that infiltrates through porous soils recharges groundwater aquifers and helps to sustain the base flow in streams.

Unless properly managed, a high infiltration rate can lead to leaching of nitrate nitrogen or pesticides and loss of phosphorus from soils that have a high level of phosphorus. Management practices such as use of no-till cropping systems and use of high residue crops and cover crops can improve infiltration by increasing the soil organic matter content.

Inherent Factors Affecting Soil Infiltration

Soil texture, or the percentage of sand, silt, and clay in a soil, is the major inherent factor affecting infiltration. Water moves more quickly through the large pores in sandy soil than it does through the small pores in clayey soil, especially if the clay is compacted and has little or no structure or aggregation.

Depending on the amount and type of clay minerals, some clayey soils develop cracks from shrinkage as they become dry. The cracks are direct conduits for water to enter the soils. Thus, clayey soils can have a high infiltration rate when dry and a slow rate when moist (cracks close). Clayey soils that do not crack have a slow infiltration rate unless they have a high content of iron oxide (red clayey soils) or they formed in volcanic ash. Management practices that improve soil organic matter content, soil aggregation, and porosity can improve infiltration.

Infiltration Management

Management practices such as using diverse high-residue crops, maintaining residue on the soil surface, using cover crops, and managing equipment traffic to avoid compaction affect infiltration by minimizing surface crusting and compaction and increasing soil organic matter content and porosity. Unless the soil is protected by plant or residue cover, the direct impact of raindrops dislodges soil particles, resulting in runoff and erosion. The rainfall simulator in figure 1 shows that more runoff occurs where there is less residue on the surface, increasing the risk of erosion. Dislodged soil particles fill in the surface pores, contributing to the development of a surface crust, which restricts the movement of water into the soil. Equipment use, especially on wet soils, and tillage can result in compaction. Compacted or impervious soil layers have less pore space, which restricts water movement through the soil profile.

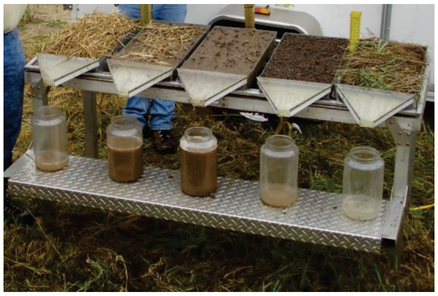

Figure 1.—Rainfall simulator.

As soil moisture content increases, the infiltration rate decreases. Soil moisture is affected by evaporation, water use by plants, residue on surface and plant cover, irrigation, and drainage. Dry soils tend to have pores and cracks that allow water to enter faster. As a soil becomes wet, the infiltration rate slows to a steady rate based on how fast water can move through the saturated soil; the most restrictive layer, such as a compacted layer; or a dense clay layer.

Soil organic matter binds soil particles together into stable aggregates, increasing porosity and infiltration. Soils that have 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 that link the upper soil layer to subsurface layers.

Long-term solutions for maintaining or improving soil infiltration include practices that increase organic matter content and aggregation and minimize runoff, disturbance, and compaction. A higher content of organic matter results in better soil aggregation and improved soil structure, increasing the soil infiltration rate.

To improve the soil infiltration rate:

- Avoid soil disturbance and equipment use when the soils are wet.
- Use equipment only on designated roads or between rows.
- Limit the number of times equipment is used on a field.
- Subsoil to break up compacted layers.
- Use a continuous, no-till cropping system.
- Apply solid manure or other organic material.
- Use rotations that include high-residue crops, such as corn and small grain, and perennial crops, such as grass and alfalfa.
- Plant cover crops and green manure crops.
- Farm on the contour.

Problems Related to Infiltration and Relationship of Infiltration to Soil Function

When rainfall is received at a rate that exceeds the infiltration rate of a soil, runoff moves downslope or ponds on the surface in level areas. Runoff on bare or sparsely vegetated soil can result in erosion. Runoff removes nutrients, chemicals, and sediment, resulting in decreased soil productivity, offsite sedimentation of bodies of water, and diminished water quality.

To determine whether runoff is likely to occur, refer to rainfall data from the nearest location that reflects the amount and duration of rainfall in the sampled area. Compare it to the infiltration rate of the area to determine whether the rate is adequate to minimize runoff. For example, tables 1 and 2 show the likely frequency (1 to 100 years) and duration of rainfall events and the amount of rainfall received during each event at two locations in Nebraska.

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

Frequency of rainfall event	**Duration of rainfall event and total rainfall (in)**		
	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

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

Frequency of rainfall event	**Duration of rainfall event and total rainfall (in)**		
	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; 1961; *Rainfall Frequency Atlas of the United States*; U.S. Weather Bureau.

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

The soil infiltration rate is most affected by conditions near the soil surface, and the rate can change drastically as a result of management.

Infiltration is rapid through large continuous pores at the soil surface, and it slows as pores become smaller. Steady-state infiltration rates typically occur when the soil is nearly saturated. These rates are given for various textural classes in table 3. They are average values and should not be generalized for all soil types.

Table 3.—Steady-state infiltration rates*

(Soils are wet deep into the profile. Values should be used only for comparing to the infiltration rate of the second inch of water applied.)

Soil type	**Steady-state infiltration rate (in/hr)**
Sand	>0.8
Sandy and silty soils	0.4-0.8
Loam	0.2-0.4
Clayey soils	0.04-0.2
Sodic clayey soils	<0.04

*Hillel, 1982.

What practices are being used that affect the infiltration rate?______________________________

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Do these practices increase or decrease the infiltration rate? Why or why not?

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Measuring Infiltration

Materials needed to measure infiltration:

____ 3- or 6-inch-diameter aluminum ring

____ Rubber mallet or weight

____ Block of wood or plastic insertion cap

____ Plastic wrap

____ Plastic bottle marked at 107 mL (3-inch ring) or 444 mL (6-inch ring) for 1 inch of water, or graduated cylinder

____ Distilled water or rainwater

____ Stopwatch or timer

Considerations:

Select representative test locations. For comparison, select locations under different management. For example, select an area where wheeled equipment has been used and one where it has not been used. For greater accuracy, make multiple measurements (3 or more) at each representative location.

The test should not be conducted when the surface layer is unusually dry. If needed, add water and then allow the water to soak into the soil before conducting the test. The measurement can also be taken after the soil has been moistened by rain or irrigation water. The infiltration rate will vary depending on the initial moisture content; therefore, the estimated initial moisture state should be documented. Avoid areas that are not typical of the area, such as animal burrows.

Infiltration test:

1. Clear all residue from the soil surface. Drive the ring into the soil to a depth of 3 inches using a rubber mallet or weight and a plastic insertion cap or block of wood. Take care to drive the ring downward evenly and vertically. Gently tamp down the soil inside the ring to eliminate gaps.
2. Cover the inside of the ring with plastic wrap, and drape it over the rim.
3. Pour 107 or 444 mL of distilled water or rainwater into the plastic-lined ring (fig. 2).

Figure 2.—Water is poured into plastic-lined ring.

4. Gently pull plastic wrap away. Record the time it takes for the water to infiltrate the soil. Stop timer when the soil “glistens.”
5. Repeat steps 2, 3, and 4 to determine the steady-state infiltration rate. Several measurements may be needed.
6. Record the results in table 4.
7. Remove the ring with the soil intact. This intact soil core can be used indoors for the respiration and bulk density tests.

Interpretations

In table 4, record the infiltration rate for the first and second inches of water applied and record the steady-state infiltration rate. Answer discussion questions. The infiltration rate is an indication of the susceptibility of the soil to runoff or ponding. Compare the rate for soils in different fields, soils of different types, and soils under different management systems.

Table 4.—Infiltration data sheet

Date: May 1, 2012									
Location	**Soil texture**	**First inch of water applied**		**Infiltration time for first inch (minutes)**	**Infiltra-tion rate (in/hr)**	**Second inch of water applied**		**Infiltration time for second inch (minutes)**	***Steady state (in/hr)**
		Start time	**End time**			**Start time**	**End time**		
Area tracked by wheeled equipment	Silty clay loam	2:00	5:00	180	0.33	5:00	8:20	200	0.30
Area not tracked by wheeled equipment	Silty clay loam	2:00	2:01	1	N/A	2:02	4:02	120	0.5
Notes:									

*Three or more measurements (inches of water) may be needed to achieve steady-state infiltration rate.

Did the infiltration rate change from the first inch of water applied to the second inch applied? Why or why not? Would a steady-state infiltration rate be achieved if a third inch of water was applied?

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Determine the rainfall patterns for your specific geographical area (tables 1 and 2 are example rainfall patterns for two locations in Nebraska and thus should not be used for all areas). How does the infiltration time compare to the expected amount of rainfall in your geographical area? Is the soil susceptible to runoff?

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How do the infiltration rates compare to the steady-state infiltration rates given in table 3? Are the rates higher, lower, or similar to those for a similar soil type? Explain.

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Glossary

Infiltration rate.—Measure of how fast water enters the soil. It typically is expressed as inches per hour, but it is recorded as minutes needed for each inch of water applied at the surface to move into the soil.

Restrictive layer.—Compacted layer or layer of dense clay, bedrock, or other restrictive material that limits infiltration below the surface of the soil.

Sodic soil.—Soil that has a high sodium content and thus a very low infiltration rate.

Soil aggregates.—Soil particles held together by organic matter and related substances. Well aggregated soils have a higher infiltration rate and a lower risk of erosion.

Soil porosity.—Amount of pore space in the soil. Soils with higher porosity have more pore space and a higher infiltration rate than those with lower porosity.

Steady-state infiltration.—The condition in which the infiltration rate does not increase or decrease as more water is added. It typically occurs when the soil is nearly saturated.