Section C

Soil characteristics that influence nitrogen and water management

Soil characteristics vary across the landscape

Organic Matter is that fraction of the soil composed of anything that once lived, including microbes, and plant and animal remains.

Parent Material is the geologic material from which soil horizons form. As an example: wind-blown loess over glacial till.

Soils vary from one field to another, and often within the same field. Soil differences certainly affect yield potential from one part of a field to another, and also impact how water and fertilizer must be managed to maintain good production levels. Some important characteristics that change across a landscape include soil texture, **organic matter** content of the top 6 to 8 inches, pH, and the thickness and density of the clay accumulation horizon.

Soils are formed by climate acting on "**parent material**" over long periods of time. The parent material can be rock that has weathered in place, or material that has been deposited by the wind, laid down by water, or brought in by glaciers. An area of soil that has the same parent material and has similar characteristics throughout is called a soil series. Different soils develop in a region as slope, drainage, vegetation, and parent materials change (*Figure C-1*).

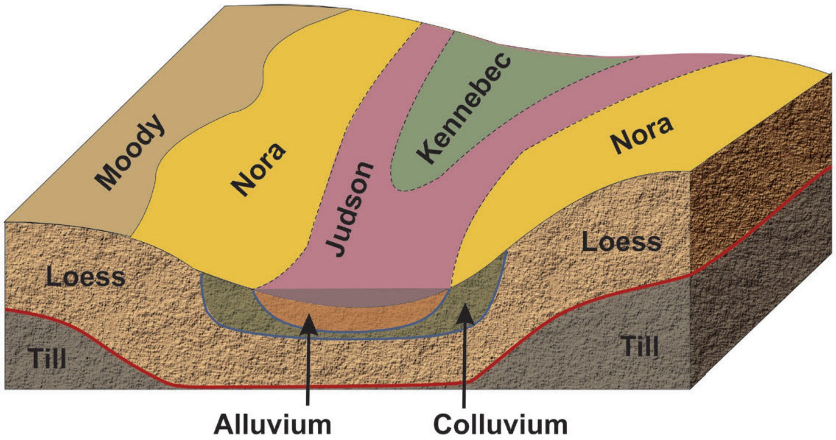

Figure C-1. Different soil series form based on their position on field topography. Note that the soil series changes from the top of the hill to the bottom land areas.

Some important features of a soil profile are shown in *Figure C-2*. Two features are particularly important to nitrogen management.

- The organic matter in the top few inches is a vast storehouse of organic nitrogen, which soil microbes slowly mineralize into a form of nitrogen that crops can use. The organic matter, together with the clay particles in the surface horizon, holds many nutrients essential for plant growth. The amount of organic matter in the surface horizon also greatly improves the soil structure and tilth.
- The clay accumulation horizon slows the rate of water drainage and nutrient loss from the upper root zone. This horizon can also limit root zone expansion if it is thick and/or compacted.

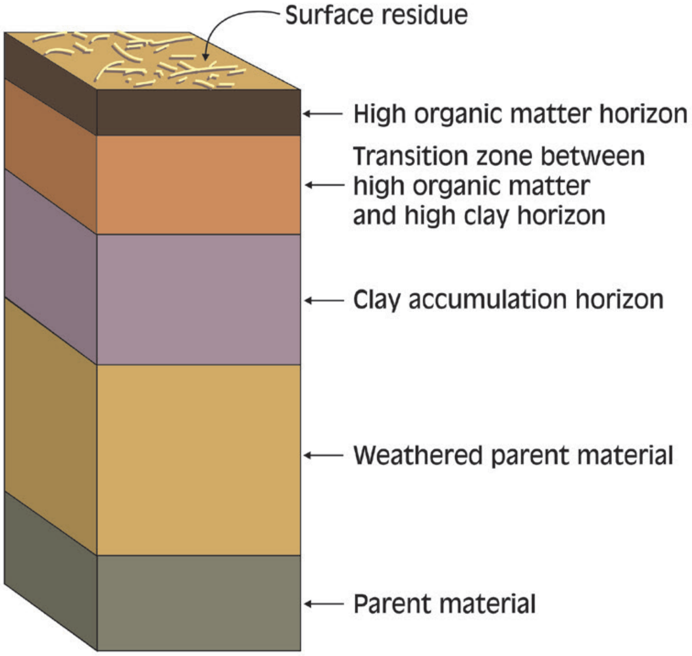

Figure C-2. A typical soil profile depicting important textural features.

Soils vary dramatically from east to west across Nebraska due to the wide range in parent materials and precipitation levels. Thus, not all soils show the characteristics shown in *Figure C-2* to the same degree. Even within the same county, parent material and soil age often require different management practices to reduce nitrate leaching. For example, a silty clay loam formed from fine-textured, wind-deposited material has a thick, high organic matter horizon, and a thick dense clay accumulation horizon. This means that a silty clay loam soil has slow internal drainage, thus nitrate leaching occurs slowly. The high organic matter means that a silty clay loam provides substantial amounts of nitrate from mineralization of organic matter over the growing season.

With all the differences between soil series and even within a soil series, in any field there can be variability in water intake, water movement and storage, and available nutrients within very short distances. If nitrate leaching losses from the root zone are to be held to a minimum, the characteristics of different soils and soil variability within fields have to be considered when planning fertilizer and water management programs.

Soil water content

Figure C-3 illustrates a volume of soil that is composed of three major components: soil particles, air, and water. The pie-chart on the lower right provides a visual indication of the relative volumes for each component. The fractions of water and air are contained in the voids between soil particles. The amount of water in a soil can be expressed in many ways, including percent water on a dry soil basis (mass water content), percent water on a volumetric basis (volumetric water content), percent of the available water remaining or percent of the available water depleted. However, the most useful methods of expressing soil water content are volumetric soil water content and percent of available water remaining.

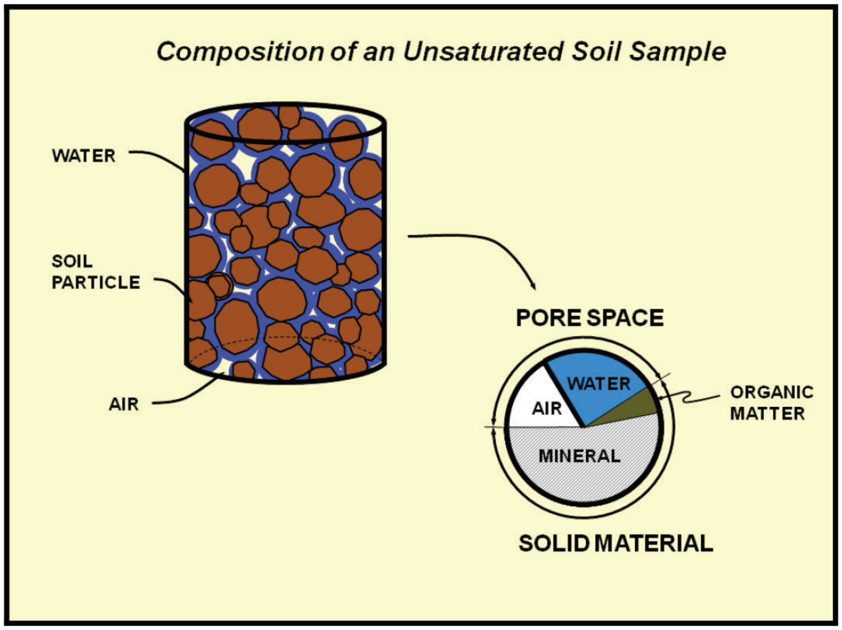

Figure C-3. Composition of an unsaturated soil core.

The *volumetric water content* represents the volume of water contained in a volume of soil. *Figure C-4* illustrates the components needed to estimate the volumetric water content. The process includes obtaining a known volume of wet soil, weighing the sample wet, drying the soil in an oven or microwave, and weighing the soil volume dry. The equation uses an equivalent value for water volume and mass of 1 gram per cubic centimeter of water. The change in weight of the soil sample between wet and dry is the water weight, which is converted to volume before dividing by the volume of the soil sample.

When thinking about water amounts per unit of land area, it is more convenient to speak in equivalent depths of water rather than volumetric water content. The relationship between volumetric water content and the equivalent depth of water in a soil layer is determined by multiplying the volumetric water content times the soil depth. For example, if soil sample is determined to have a volumetric water content of 30% water in a foot of soil sample, the equivalent depth of water in the soil is 3.6 inches per foot (0.30 x 12).

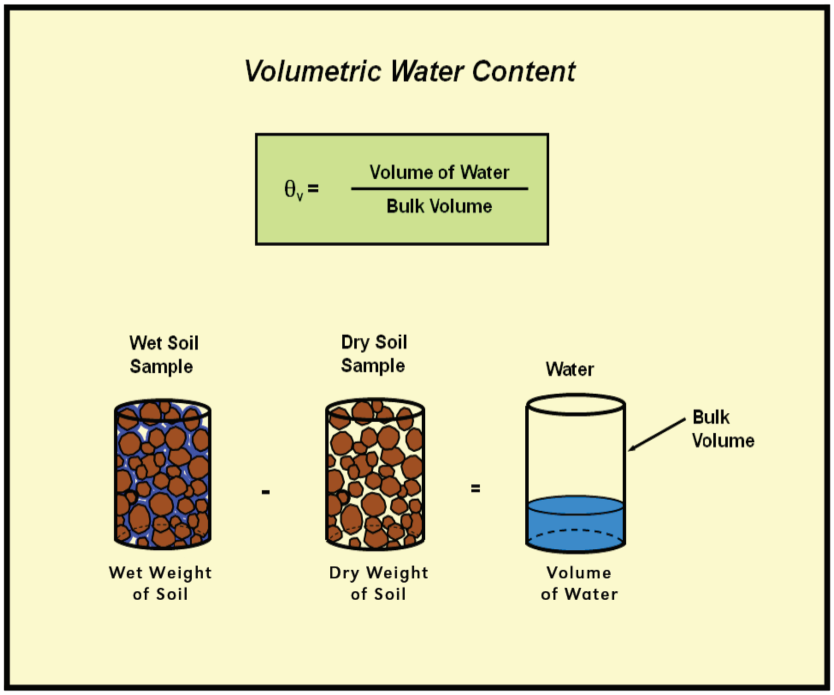

Figure C-4. Concept of how volumetric soil water content is determined

Plant available soil water

Plant available water is the amount held by the soil between two limits: **field capacity** (the upper limit) and **permanent wilting point** (the lower limit) (*Figure C-5*). Plant available water is determined primarily by soil texture, although soil structure is also important in fine-textured soils. Right after irrigation or precipitation, the soil water content may be temporarily above field capacity (very temporary storage in *Figure C-5*). If this water is not used by the plant or allowed

Field Capacity represents the amount of water remaining in the soil after drainage due to gravitational forces has ceased.

Permanent Wilting Point is the water content of a soil when most plants growing in the soil wilt and fail to recover.

Plant Available Water is the portion of water contained in the soil that can be absorbed by plant roots.

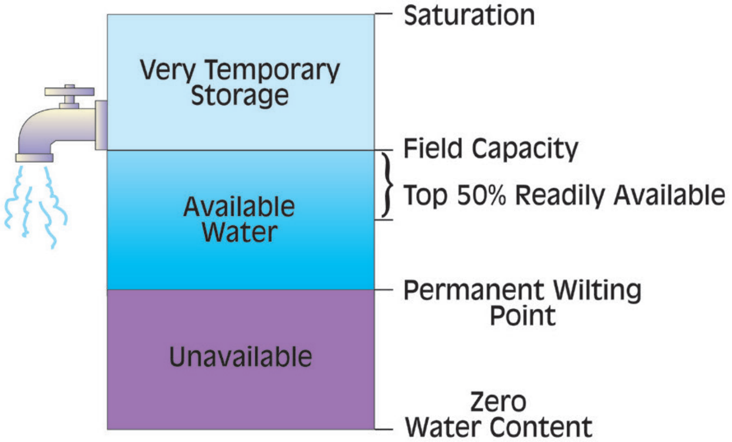

Figure C-5. Schematic drawing of a water tank analogy to depict key plant available soil water availability factors.

to drain, the soil will remain saturated. However, in most Nebraska soils the excess water drains in two or three days due to the pull of gravity. Once the excess water has drained, soil water content is at field capacity.

Between field capacity and the permanent wilting point, plants are able to remove soil water to meet crop demand. As the **plant available water** approaches the permanent wilting point, the water content of the soil becomes so dry that plants wilt and do not recover. About half the water held between field capacity and permanent wilting is considered to be readily available water. In general, if a plant is irrigated by the time the readily available water in the root zone has been used, there will be no crop stress. Note that below the wilting point there is still some water held in the smallest pores, but it not available to plants.

Soil Water Potential or **Matric Potential** is an indicator or measure of soil water content expressed in kilopascals, bars, or centibars.

Soil Water Retention Curve is a graph displaying the change in water content in response to the application of tension.

Soil water potential is an indicator or measure of the soil water content and is often expressed in units of kilopascals (kPa), bars, or centibars. The component that dominates the release of water from the soil to plants is the ***matric potential***. The strength of the matric force depends on the distribution of the soil pore sizes. Large pores will freely give up pore water to plants or to drainage due to the gravitational forces. The magnitude of the matric potential is expressed as soil water tension and is the basis for monitoring soil water content that will be discussed in a future section of this manual. A curve representing the relationship between the soil water tension and volumetric water content is known as a ***soil water retention curve*** *(Figure C-6)*. Soil-water retention curves are often used to define the amount of soil water available to plants. *Figure C-6* depicts the three important levels of soil matric potential, including the wilting point.

The academic definition of wilting point is the soil water content corresponding to a soil matric potential of -15 bars. The volumetric water content at wilting point is given in *Figure C-6* for three soil types. Similarly field capacity is often defined as the soil water content at a soil water potential of -0.33 bars. **Note:** the volumetric water contents for the wilting point and field capacity designations for three soil textures shown in *Figure C-6*. The plant available water capacity of a soil is often expressed in units of depth of available water per unit depth of soil, i.e., inches of water per foot of soil. For the sandy loam soil, the volumetric water content at field capacity is 0.23 inches of water per inch of soil depth or 23%, and the volumetric water content at wilting point is about 0.10 or 10%. Using these two numbers we can estimate the plant available water capacity for that sandy loam soil as 0.13 (0.23-0.10). In this example, the plant available water content is 0.13 in/in or 1.56 inches of water per foot of soil.

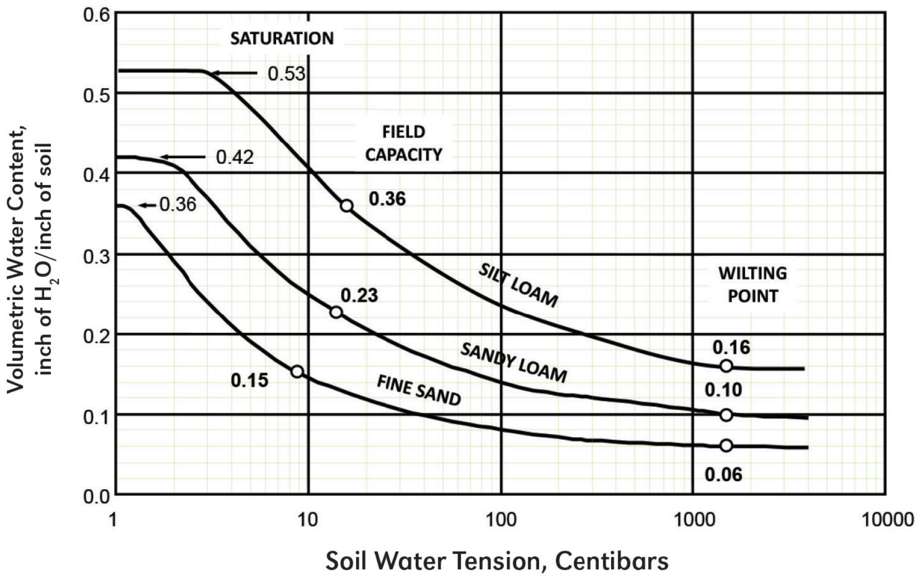

Figure C-6. Soil water retention curves for three soil textures.

> The soil water retention curve and the volumetric water content at saturation, field capacity, and permanent wilting point are specific to each soil texture classification.

Data for soil water holding properties are available from various sources. County Soil Survey Reports and the Web Soil Survey from the USDA-NRCS normally list these data. Ranges of values for available water holding capacity for some typical soil texture classes are listed in *Table C-1*.

Infiltration

Soil water is replenished by the process called ***infiltration***, the entry of water into the soil. Infiltration is described in terms of the rate water enters the soil (i.e., the depth that infiltrates per unit of time). Infiltration is very important in irrigation since the goal is to supply water to the root zone to meet plant needs. The goal is that all of the applied irrigation water and precipitation enters the soil, thereby minimizing the amount of water that runs off the soil surface.

> **Infiltration** is the passage of water through the air-soil interface and into the soil.
>
> **Infiltration rate** is the rate water enters into the soil in inches per hour.

The curves shown in *Figure C-7* illustrate changes in **infiltration rate** for three soil textures. The curves show that initially the infiltration rate is very high but as infiltration time progresses, or more correctly, as the amount of water that has infiltrated increases, the rate of infiltration decreases. **If water application continues long enough the infiltration rate gradually approaches a constant or steady rate, sometimes called basic infiltration rate.**

Research has shown that coarser-textured (sandy) soils have greater infiltration rates than fine- (clay) and medium-textured (loam) soils. Thus, typically more precipitation and irrigation will infiltrate into a sandy soil before runoff begins. Remember from earlier in this section that sandy soils also have relatively lower soil water-holding capacities. Hence the combination of greater infiltration rates and lower water-holding capacities results in a greater potential for deep percolation and nitrate-nitrogen leaching.

The combination of greater infiltration rates and lower soil water holding capacity results in a greater potential for deep percolation and nitrate-nitrogen leaching.

Table C-1. Available soil water holding capacity of representative soil textural classes in inches of water per foot of soil depth (inch of H_2O/inch of soil).

	Soil Layer and Depth Interval		
Soil Textural Class	**Surface Soil 0-12 inches**	**Subsoil 12-36 inches**	**Lower Horizon 36-60 inches**
Coarse sand and gravel	0.48 - 0.72	0.36 - 0.60	0.25 - 0.50
Sands	0.84 - 1.08	0.72 - 0.96	0.60 - 0.84
Loamy sands	1.20 - 1.44	1.08 - 1.32	0.96 - 1.20
Sandy loams	1.56 - 1.80	1.44 - 1.68	1.32 - 1.56
Fine sandy loams	1.92 - 2.16	1.80 - 2.04	1.44 - 1.92
Very fine sandy loam	2.04 - 2.28	1.92 - 2.16	1.92 - 2.16
Loam	2.40 - 2.64	2.04 - 2.28	2.04 - 2.28
Silt loams	2.40 - 2.76	2.16 - 2.40	2.16 - 2.40
Silty clay loams (<35% clay)	2.52 - 2.76	2.16 - 2.40	2.16 - 2.40
Silty clay loams (>35% clay)	2.04 - 2.40	1.92 - 2.16	1.92 - 2.16
Sandy clay loams	2.16 - 2.40	1.92 - 2.16	1.80 - 2.04
Clay loams (<35% clay)	2.28 - 2.64	2.04 - 2.28	1.92 - 2.16
Clay loams (>35% clay)	1.92 - 2.28	1.80 - 2.04	1.68 - 1.92
Silty clays (<50% clay)	1.56 - 2.04	1.32 - 1.92	1.20 - 1.56
Silty clays (>50% clay)	1.20 -1.68	1.20 - 1.44	0.96 - 1.44
Clays (<50% clay)	1.44 - 1.92	1.20 - 1.80	1.20 - 1.44
Clays (>50% clay)	1.20 - 1.68	0.96 - 1.44	0.96 - 1.44

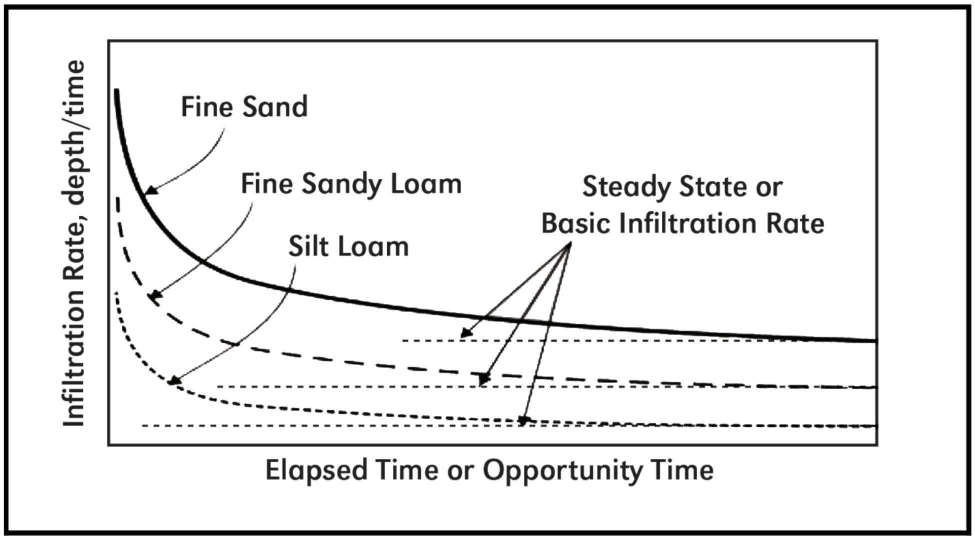

Figure C-7. Infiltration rate vs. infiltration opportunity time graph for a fine sand, fine sandy loam, and silt loam soil.

Intake family

The USDA-NRCS has rated soils for their ability to infiltrate water. Soils are assigned to representative infiltration classes called the **Intake Family** based upon extensive field measurements across the nation. Soils classified in the Intake Families of 0.1, 0.3, 0.5, and 1.0 are generally those that are well suited for irrigation but that have potential for runoff. Some sandy soils are classified as Intake Family 1.5 but these soils rarely have runoff problems and are not very well-suited for furrow irrigation. Intake Family classifications are available from the Natural Resources Conservation Service. Field managers should note that the Intake Family is a general classification system for soils. Actual infiltration rates can vary considerably due to tillage, residue, and other cultural practices.

Intake Family is a means of classifying or grouping of soil mapping units based on similarities of soil infiltration rates.

For More Information

USDA-NRCS. 1999. KS652.0204 State supplement-soils. Chapter 2 in USDA-NRCS National Engineering Handbook- Part 652. *http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_031591.pdf*