SL268

Soils and Fertilizers for Master Gardeners: Soil Physical Properties[1]

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This article is part of a series entitled *Soils and Fertilizers for Master Gardeners*. The rest of the series can be found at http://edis.ifas.ufl.edu/topic_series_soils_and_fertilizers_for_master_gardeners. A glossary can also be found at http://edis.ifas.ufl.edu/MG457.

The physical properties of a soil influence its ability to support plant growth, cycle nutrients, hold water, act as an environmental filter or even support a building. Soil physical properties are dictated by the type and arrangement of soil particles. This publication describes some of the basic physical properties of soil.

Composition of the Soil

A soil is a three-dimensional natural body comprised of solids, liquid, and gas that occurs on the land surface. In general, soil consists of approximately 45% mineral material, 5% (or less) organic matter and 50% pore space (which is occupied by air and/or water). In Florida, most soils (with the exception of muck soils) contain very little organic matter. Also, the proportion of air and water that comprise a soil changes based on variations in rainfall, temperature, and other aspects of the climate.

The mineral fraction of the soil is made up of particles that fall into three different size classes: sand (0.05 – 2.0 mm diameter), silt (0.002 – 0.05 mm), and clay (<0.002 mm). The terms sand, silt, and clay only describe the absolute size of the soil particles, not what minerals make up the soil particles. As the size of the particles decrease, their influence on nutrient and water holding capacity increases. Smaller particles have more surface area available for interaction with nutrients and water molecules.

To illustrate the concept of surface area, picture a Rubik's Cube® game. When assembled, the cube has six faces, each of which is 3 inches wide x 3 inches long. Therefore, each face has a surface area of 9 square inches, for a total surface area of 54 square inches. The total outside surface area of the Rubik's Cube® would be analogous to the surface area of a large sand particle.

Because very few people ever solve the puzzle, it inevitably gets disassembled into 27 cubes that each have six faces, each of which is 1 inch wide x 1 inch

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long. Therefore, each face has a surface area of 1 square inch for a total surface area of 6 square inches. Since there are 27 of these small cubes in each Rubik's Cube®, there is a total of 162 square inches of surface area. This would be analogous to the surface area provided by 27 single clay particles (small cubes), which in this case would be the same size as one sand particle (large assembled cube).

Soil Texture and Textural Classes

Soil texture is the relative proportion of sand, silt and clay particles in the soil. In general, soils dominated by sand-sized particles are coarse-textured or sandy soils, soils dominated by silt-sized particles are moderate-textured or loamy soils, and soils dominated by clay-sized particles are fine-textured or clayey soils. Soils can be further grouped into twelve soil textural classes based on the proportion of sand, silt and clay as defined by use of the soil textural triangle (Figure 1). Soil textural class can be determined in the laboratory or estimated by a trained soil scientist using a "feel" method in the field. In Florida, surface soils tend to fall in the sandy, loamy sand or sandy loam textural classes, which are located in the bottom left-hand corner of the textural triangle. Knowledge of the soil texture can provide clues about other important soil properties, such as water holding capacity and fertility. For example, sandy soils are often well drained with low fertility, organic matter and water holding capacity. For more detailed in-formation about soil texture and textural classes, see EDIS publication *Soil Texture* http://edis.ifas.ufl.edu/SS169.

Soil Structure

In the soil, particles can be held together in groups called aggregates (also called peds). These soil aggregates, and how they occur in the soil profile, determine the soil structure. Soil structure impacts the ability of a soil to transmit and store air, water and nutrients. Soil aggregates form in the soil as a result of physical and chemical processes. Soil organic matter acts as a binding agent for soil particles, which promotes particle aggregation and hence, good soil structure. Since most Florida soils naturally have very small amounts of organic matter, addition of organic

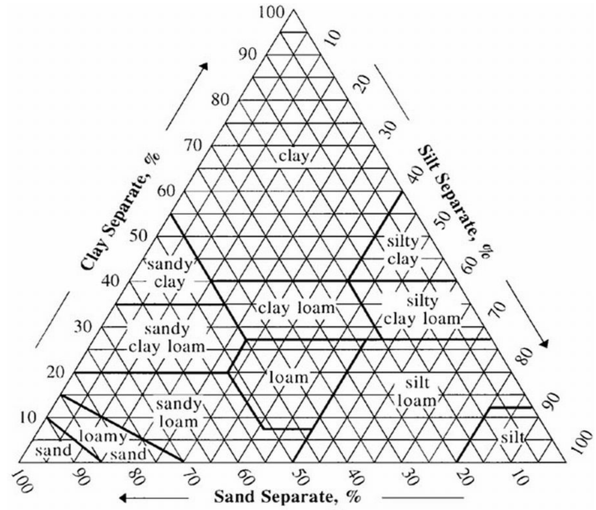

Figure 1. The soil textural triangle is used to categorize soils based on the proportion of sand, silt, and clay sized particles. Credits: USDA

amendments will promote the formation of soil aggregates and improve soil structure.

The types of soil aggregates are granular, platy, blocky, prismatic and columnar (Figure 2). Some soils do not have visible soil structure and are considered to be structureless. There are two types of structureless soils, single-grain and massive (Figure 2) . Almost all of Florida's soils are classified structureless (single-grain) because they are dominated by sand-sized particles. Soil aggregates rarely form in these soils, even when there is adequate soil organic matter. Therefore, additions of organic materials to Florida soils are unlikely to improve soil structure.

Soil Density

The solid (mineral and organic) particles that make up a soil have specific **particle density**, which is defined as the mass of solid particles in a unit volume. The particle density of a soil is not affected by particle size or arrangement; rather it depends on the type of solid particles present in the soils. Mineral soil particles have a higher particle density than organic matter because mineral particles are much heavier on a unit volume basis. The average particle density of a mineral surface soil is about 2.65 grams per cm^3 (which is equivalent to 165 pounds per cubic foot!).

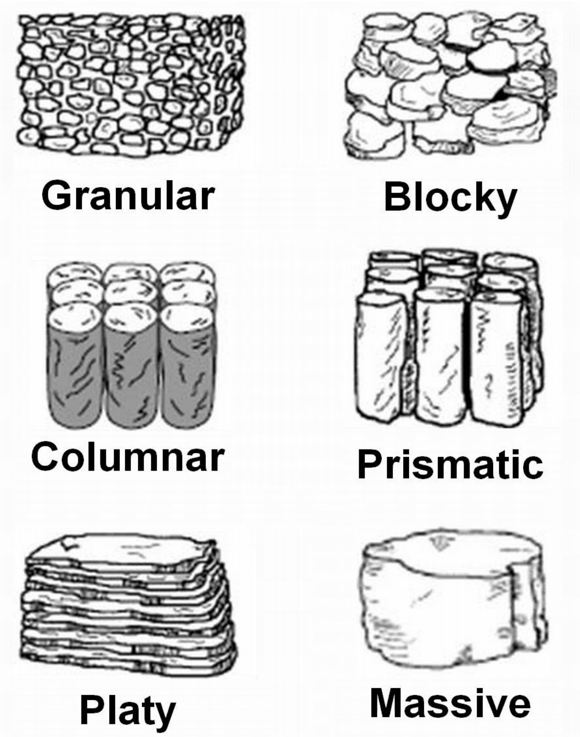

Figure 2. Common types of soil structure. Credits: University Corporation for Atmospheric Research

Soil bulk density is the mass of dry soil per unit volume. Unlike the measurement of particle density, the bulk density measurement accounts for the spaces between the soil particles (pore space) as well as the soil solids. Soils with a high proportion of pore space have low bulk densities and vice versa. Sandy soils with low organic matter tend to have higher bulk density than clayey or loamy soils. The typical range in bulk density values of non-compacted soils are listed in Table 1. Soil bulk density is usually higher in subsurface soils than in surface horizons, in part due to compaction by the weight of the surface soil.

Soil management can impact soil bulk density. For example, driving heavy equipment over the soil during construction or agricultural production can compact the soil and increase the bulk density (Table 1). When soils reach high bulk densities, root penetration and water infiltration can be reduced. Trying to grow plants in soils with high bulk density is essentially the same as trying to grow them in a brick or rock.

Soil Pores and Water

As mentioned earlier, the portion of the soil volume occupied by air and water is called pore space. The amount of pore space is determined by the arrangement of the soil particles. The amount of pore space is low when soil particles are very close together, such as in compacted soils. The amount of pore space is higher when soils have high organic matter and the soil particles are arranged into soil aggregates (i.e., good soil structure). Sandy soils normally have 35-50% pore space, while medium to fine-textured soils have 40-60% pore space, or more in cases of high organic matter and granulated structure. Pore space decreases with soil depth.

The ability of the soil to hold and transmit water and air is impacted by the amount of pore space in the soil and by the size (diameter) of those soil pores. Soil pores can be classified into two main groups depending on the diameter of the individual pore. **Macropores** are large diameter pores (>= 0.1 mm) and **micropores** are small diameter pores (< 0.1 mm). Coarse-textured soils contain a large proportion of macropores, while fine-textured soils tend to have a high proportion of micropores.

Under normal conditions, soil micropores are usually filled with water, while macropores are filled with air. However the amount of air or water in the pore spaces will be impacted by several factors. For example, precipitation and irrigation events add water to soil pores, while drainage, evaporation or plant uptake remove water from soil pores. Because water is removed easiest from macropores, they will be the first to empty. Therefore, coarse-textured soils are droughty because they do not have the ability to hold a sufficient amount of water for optimum plant growth. In contrast, the movement of water and air through micropores is very slow. Therefore, it is important for fine-textured soils to have good soil structure, otherwise the amount of air (oxygen in particular) in the pores may not be sufficient to support root growth.

Summary

Natural surface soils consist of approximately 45% mineral material, 5% (or less) organic matter, 50% air or water filled pore space. The proportion of sand, silt, and clay particles in the soil determines soil texture. When soil particles are held together in soil aggregates, the soil has structure. Soils with no visible aggregates are structureless. The type of particles that comprise the soil dictate the particle density, which is relatively constant for mineral soils. Bulk density of soils accounts for the soil particles and pore space per unit volume. Soils have a combination of large macropores that transmit air and water easily, and micropores that tend to be filled with water. These soil physical properties influence water, air, and nutrient movement, which impact plant growth.

References

Brady, N.C. and R.R. Weil. 2002. *The Nature and Properties of Soils*. Prentice Hall, Upper Saddle River, NJ. 13th Edition. p. 121-175.

Table 1. Bulk density values for soils and other reference materials.

Material	Normal Bulk Density	Compacted Bulk Density
Fine-textured soil	1.0-1.6 g/cm^3 (62-100 lbs/ft^3)	1.55 g/cm3 (97 lbs/ft^3)
Coarse-textured soil	1.2-1.8 g/cm^3 (75-112 lbs/ft^3)	1.75 g/cm^3 (109 lbs/ft^3)
Red brick	1.92 g/cm^3 (120 lbs/ft^3)	____
Limestone (solid)	2.61 g/cm^3 (163 lbs/ft^3)	____