In the Name of God

Unit 2: Soil Science

Introduction

Soil science is the study of soil as a **natural resource** on the surface of the earth including **soil formation, classification and mapping; physical, chemical, biological, and fertility** properties of soils; and these properties in relation to the use and management of soils. Sometimes terms which refer to branches of soil science, such as **pedology** (formation, chemistry, morphology and classification of soil) and **edaphology** (influence of soil on organisms, especially plants), are used as if synonymous with soil science. The diversity of names associated with this discipline is related to the various associations concerned. Indeed, **engineers, agronomists, chemists, geologists, geographers, ecologists, biologists, microbiologists, sylviculturists, sanitarians, archaeologists, and specialists in regional planning**, all contribute to further knowledge of soils and the advancement of the soil sciences. Soil scientists have raised concerns about how to preserve soil and arable land in a world with a **growing population**, possible future **water crisis**, increasing **per capita food consumption, and land degradation**.

History

Vasily Dokuchaev (Fig. 1), a Russian geologist, geographer and early soil scientist, is credited with identifying soil as a resource whose distinctness and complexity deserved to be separated conceptually from geology and crop production and treated as a whole.

Previously, soil had been considered a product of **chemical transformations** of rocks, a dead substrate from which plants derive **nutritious elements**. Soil and **bedrock** were in fact equated. Dokuchaev considers the soil as a natural body having its own **genesis** and its own history of development, a body with complex and multiform processes taking place within it. The soil is considered as different from bedrock. The latter becomes soil under the influence of a series of soil-formation factors (climate, vegetation, country, relief and age). According to him, soil should be called the "daily" or outward **horizons** of rocks regardless of the type; they are changed naturally by the common effect of water, air and various kinds of **living and dead organisms.**

A 1914 encyclopedic definition: "the different forms of earth on the surface of the rocks, formed by the breaking down or weathering of rocks" serves to illustrate the historic view of soil which persisted from the 19th century. Dokuchaev's late 19th century soil concept developed in the 20th century to one of soil as **earthy material** that has been altered by living processes. A corollary concept is that soil without a living component is simply a part of earth's outer layer.

Further refinement of the soil concept is occurring in view of an appreciation of energy transport and transformation within soil. The term is popularly applied to the material on the surface of the Earth's moon and Mars, a usage acceptable within a portion of the scientific community. Accurate to this modern understanding of soil is Nikiforoff's 1959 definition of soil as the "excited skin of the sub aerial part of the earth's crust".

Figure 1. Vasily Dokuchaev, the father of soil science

Definition of Soil

We have several definitions of soil depending on the discipline providing the definition:

1- **Geologic definition:** loose surface of the earth as distinguished from **solid bedrock**. (Support of plant life not required)

2- **Traditional definition:** material which **nourishes** and supports **growing plants**. (Includes rocks, water, snow, and even air – all of which are capable of supporting plant life)

3- **Component definition:** mixture of **mineral matter**, **organic matter**, water and air. (Example: Loam soil = 45% mineral matter, 5% organic matter, 25% water, and 25% air). (Fig. 2).

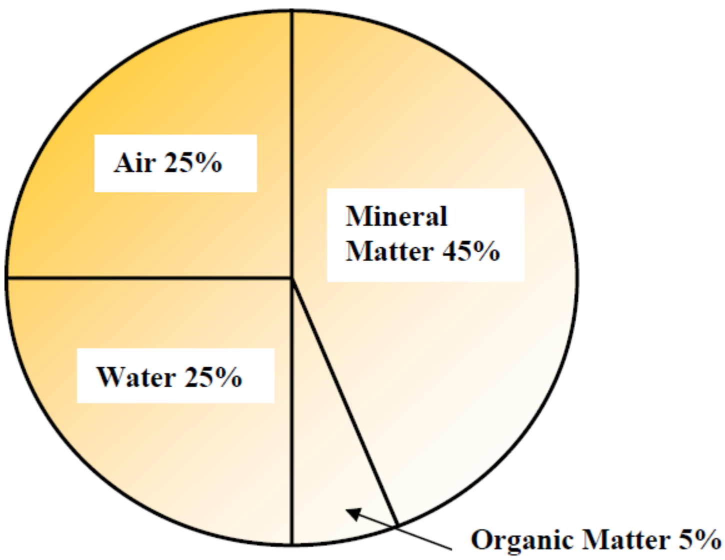

Figure 2. Composition of an average soil

4- **Soil Taxonomy definition:** collection of **natural bodies** of the earth's surface, in places modified or even made by man or earthy materials, containing living matter and supporting or capable of supporting plants out-of-doors. Its upper limit is air or shallow water. At its margins it grades to deep water or to **barren areas** of rock or ice. Its lower limit is the lower limit of biologic activity, which generally coincides with the common **rooting depth** of **native perennial plants**, the depth to which **soil weathering** has been effective, or both.

5- **As a Portion of the landscape:** collection of natural bodies occupying portions of the earth's surface that support plants and that have properties due to the integrated effect of climate and living matter, acting upon **parent material**, as conditioned by **relief**, over periods of time.

Composition of Soil

Soils have four major **components**: (a) mineral matter, (b) organic matter, (c) air, and (d) water.

Air and water occupy the **pore spaces** in soils. Pore spaces are the **voids** between the soil **particles**. Air and/or water occupy approximately half the volume of soil. **Fine-textured soils** have more total pore space than **coarse-textured soils**. As soils absorb water, the air space decreases. Generally speaking, it is desirable to have a soil which, when **well drained**, will have about half or its pore spaces filled with water. Soils which have all of their pore space filled with water for several days after a rain are considered in many of the definitions of wet soils within NRCS programs.

Except for **gravel** and rocks that occur occasionally in soils, there are three **fractions, sand, silt, and clay.** Sand particles are large enough to be seen without the **aid magnification** and give soils a **gritty feel**. Larger silt particles can barely be seen by the eye, and the smaller silt particles can be seen only with the aid of a microscope. Silt feels smooth within rubbed between the thumb and fingers and feels much like talcum powder or wheat flour. Clay includes the fraction smaller than silt and feels **sticky and plastic** when wet, and **harsh and hard** when dry. Since clay includes all particles below the size of silt, this fraction contains the available plant nutrients not contained in the organic matter. Different organizations give different size categorizations for soil particles based on their use and objectives. Figure 3 shows different size classifications of mineral matter of a soil.

The organic matter of soils is made up of **undecomposed** and **partially decomposed residues of plants and animals** and the **tissue of living and dead microorganisms**. Organic matter contains appreciable quantities of **nitrogen, phosphorus and sulfur** which become available to **higher plants** as decomposition occurs. Furthermore, the decomposition of organic matter helps to produce substances that make all of the plant nutrients more available. From a physical point of view, organic matter improves the **aeration of soils**, increases the **water-holding capacity** of the soil, and contributes to **aggregate stability** by supplying food for **microorganisms** whose function it is to produce chemicals which hold the soil particles together.

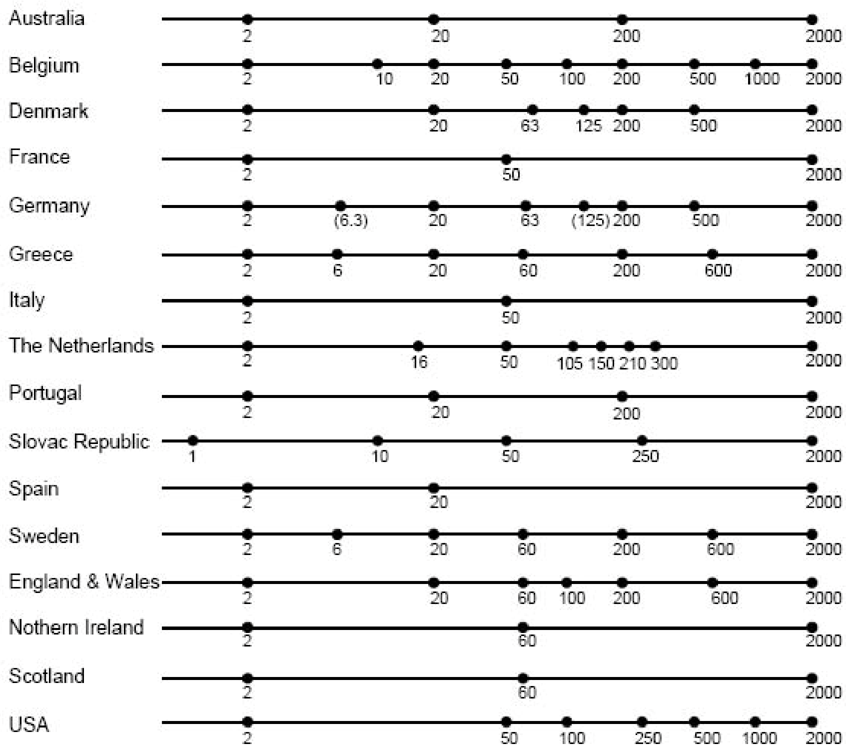

Figure 3: Different soil particle size classification by countries

Soil Profile

A soil is a three-dimensional natural body in the same sense that a hill, valley, or mountain has three dimensions. By **digging or augering a hole in the soil**, you may retrieve some soil material, and, you can take this sample of soil material into the laboratory and analyze its contents, but you must go into the field to study a soil as a natural body. Soils occur on landscapes and are delineated on **aerial photographs** by **trained soil scientists**. These delineations are called **polygons or polypedons**, and they represent soil areas that are similar with regard to the intended uses of that soil. Polypedons have many **pedons** (soil profiles) included within their boundaries. See Figure 4 for a schematic of this relationship.

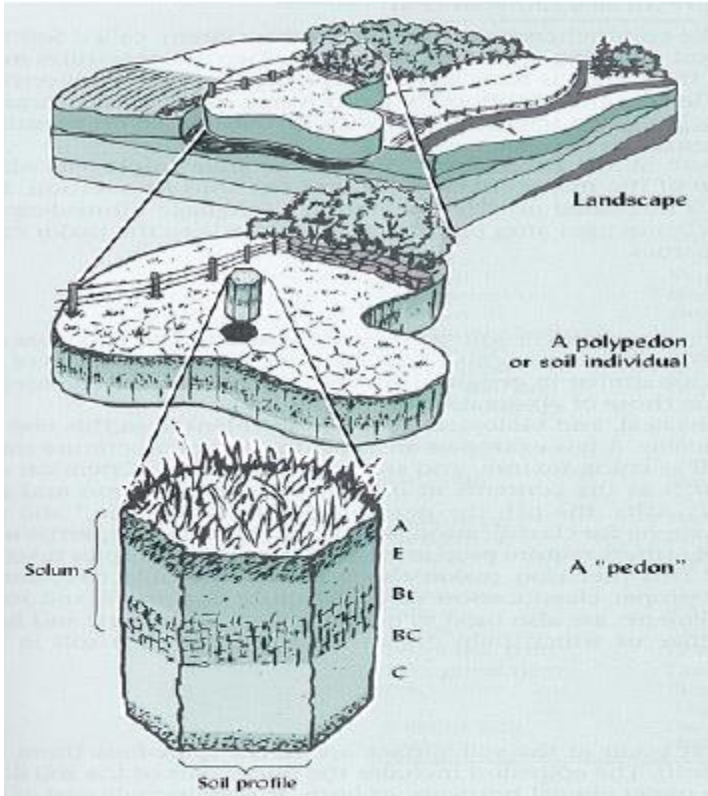

Figure 4: Relationship of Landscapes to soil polygons and a soil profile (pedon)

Soils range in depth form just a few inches to tens of meters and in many instances they have been transported many kilometers from the site of their initial formation and then **deposited** over materials such as bedrock which is much different than the **original source of the soil** materials. The effects of five soil forming factors alter the soil material: climate, time, relief, organisms, and parent material. These factors act together to differentiate individual bodies of soil. This is accomplished through four basic processes acting on the parent material to alter its properties and differentiate one soil from another. These are (a) **Translocations**, (b) **Transformations**, (c) **Additions**, and (d) **Losses** (Fig. 5).

It is the interaction of these soil forming factors in various combinations that gives us the great variety of soils we see today. There are many variations within each factor, and even if there were only 10 gradations in each factor, there would be 10^5, or 100,000 different combinations, which would mean 100,000 different soils. In truth, no two soils are expected to be just alike, but soils, which are similar, are grouped together for purposes of **classification** for cultural practices and uses.

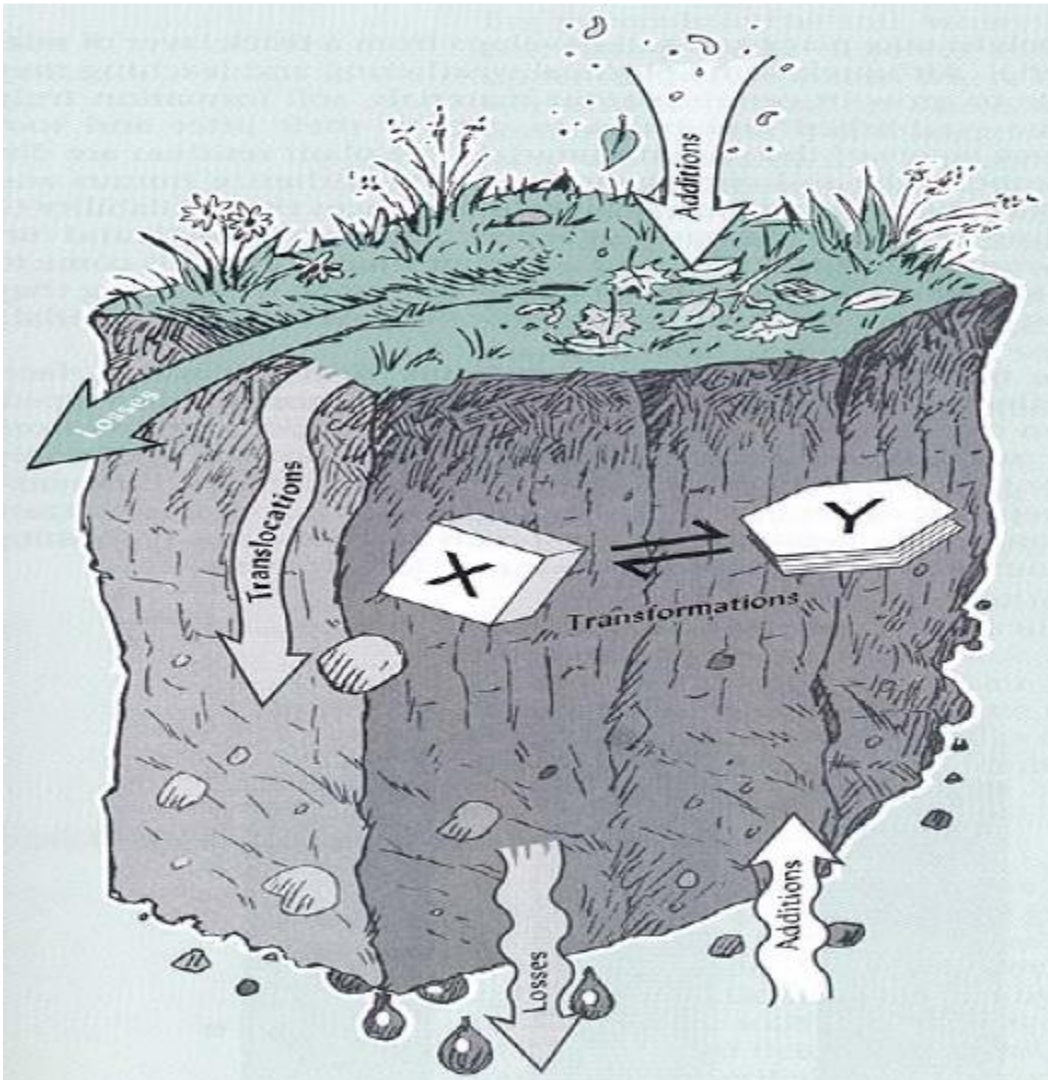

Figure 5: Soil forming processes

The effects of these soil forming factors (**weathering**) result in the formation of layers within the soil from the surface down to varying **depths** depending on the **intensity of the weathering**. These layers are called **horizons**.

The combination of these layers in a sequence from the surface of the soil down represents a **soil profile**. **Road cuts** and other man made **excavations** can expose soil profiles and serve as windows to the soil. Observing how soils exposed in these excavations vary from place to place can add a fascinating new dimension to our understanding of soils. Once you have learned to interpret the different horizons, soil profiles can warn you about potential problems in using the land as well as tell you about the environment and history of the region. For example, soils developed under **grasslands** may have a very different soil profile than those developed under **forestland**.

The layers in a soil profile are called horizons. Horizons within a soil survey vary in **thickness** and have somewhat **irregular boundaries**, but all of the boundaries generally **parallel** the earth's surface. Since the weathering of the soil profile starts at the earth's surface and works its way downward, the **uppermost layers** have been changed the most, while the **deepest layers** are most similar to the original parent material exceptions to this vertical aging process occur when **transport mechanisms** move the soil material and deposit it on the surface of previously formed soil profiles. Soil horizons are sometimes very easily identified and at other times are very gradual and faint. The horizons recognized in soil profiles are identified by letters A, E, B, C, O, and R. Refer to (Fig. 6) to see the idealized relationship of some of these horizons.

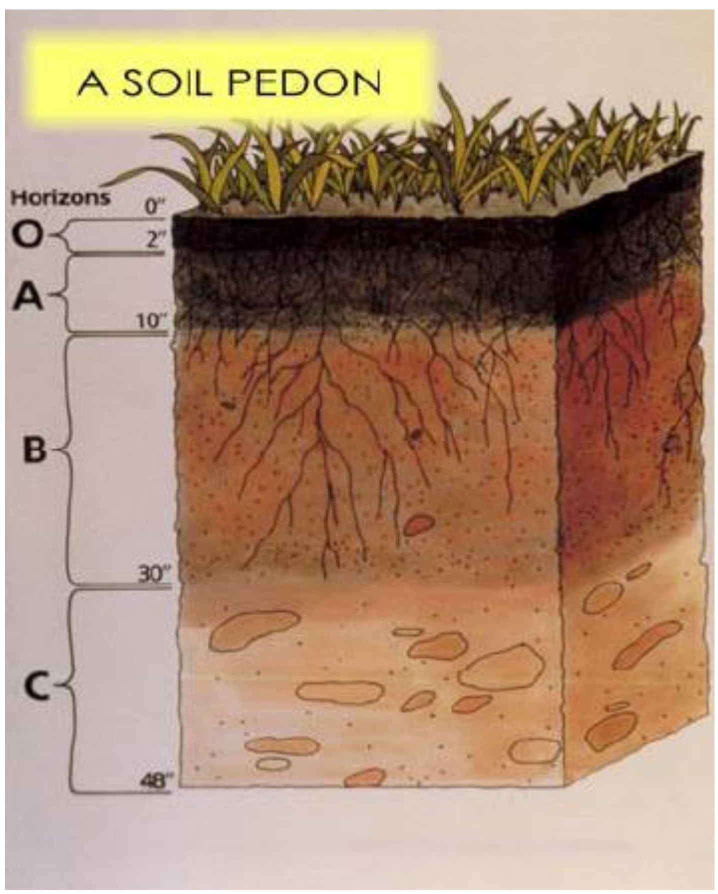

Figure 6: Idealized soil profile showing some of the soil horizon relationships

Soil Texture

Soil texture is determined by the relative proportions of sand, silt, and clay in the soil. These proportions are placed into various classes to aid in communicating to others the significance of the various combinations. Each class name has maximum and minimum percentages of each fraction. A triangle showing the range in limits for each fraction and the various class names associated with these limits is called **the Soil Textural Triangle** (Fig. 7).

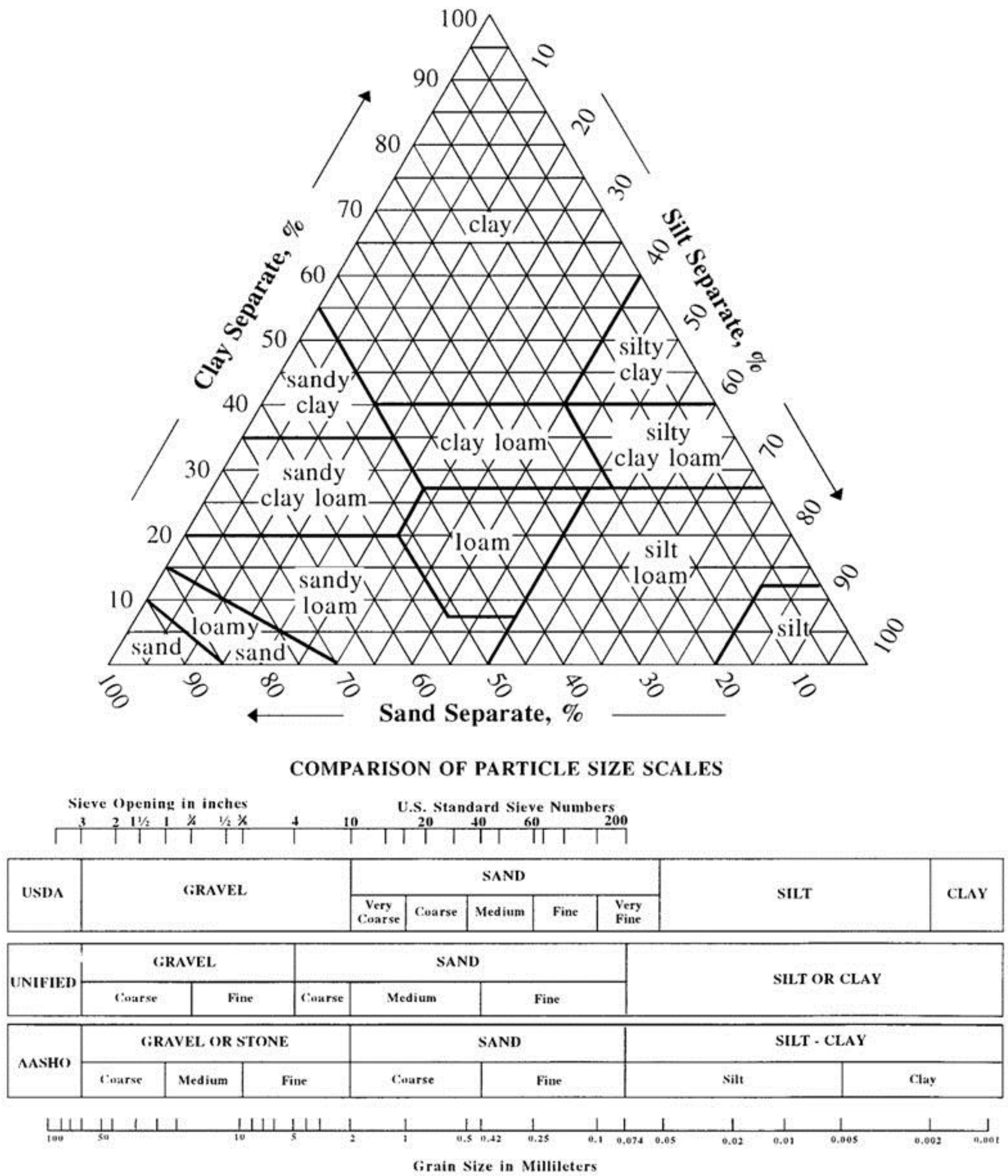

Figure 7: The soil textural triangle

Soil Structure

Structure refers to the arrangement of soil particles. Soils made up of practically all sand or all silt do not show any appreciable structural arrangement because of a lack of the **binding properties** provided by clay. A **well-developed structure** usually indicates the presence of clay. Soil structure is classified into various classes. There are three major classes and several sub-classes. They are as follows: **Structureless** which includes ***Single grain* and *Massive***; with structure which includes ***Granular, Platy, Wedge, Blocky, Prismatic,* and *Columnar***; and Structure Destroyed which includes ***Puddled*** (Fig. 8).

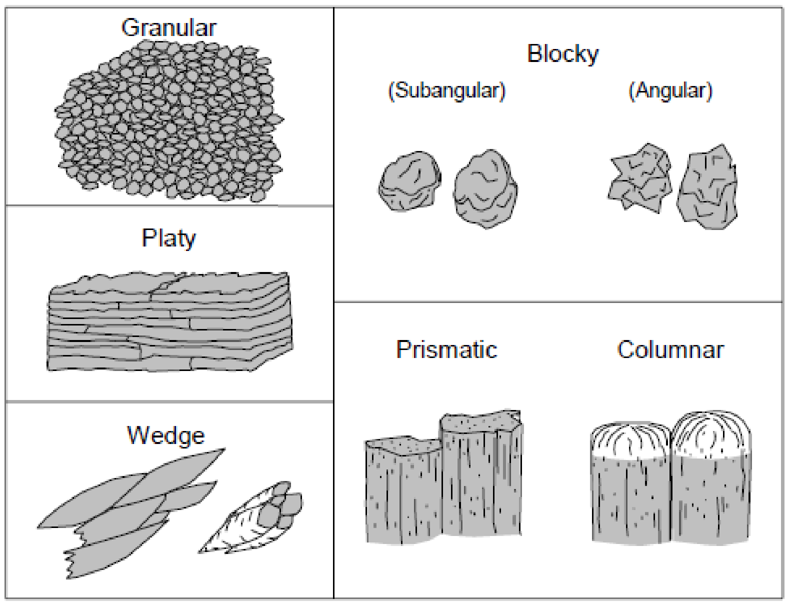

Figure 8: Soil structures

Soil structure is of particular importance in the **absorption of water** and the circulation **of air**. A desirable structure should have a high proportion of **medium-sized aggregates** and an appreciable number of large pores through which water and air can move. Structure of both the B horizon and the A horizon is very crucial to **proper drainage, infiltration, and productivity**. In soils with poor structure, **root penetration** is limited thus reducing the plants access to water and nutrients. Structure of the A horizon has received a great deal of attention because of its relation to (a) **seedbed preparation**, (b) **erosion potential**, (c) **aeration**, (d) **water infiltration**, and (e) overall **soil health**.

There are three very important aspects of soil structure. They are (a) the arrangement into aggregates of a desirable shape and size, (b) the stability of the aggregate, and (c) the **configuration of the pores**, that is, whether or not they are connected by channels or isolated. Aggregates that are stable in water permit a greater rate of absorption of water and greater **resistance to erosion**. Aggregates that are **unstable** in water tend to **slake and disperse**. These aggregates, when exposed to **raindrops**, are particularly subject to dispersion and the resultant **crusting of soils**. This crusting greatly affects **seeding emergence**, and increases **runoff** and **erosion**.

The stability of aggregates is due to the **kind of clay**, the **chemical elements** associated with the clay, the nature of the products of **decomposition or organic matter**, and the nature of the **microbial population**. The **expanding type of clay** is more likely to produce unstable aggregates, other things being equal. An excess of **sodium** associated with clays tends to cause dispersion. A high proportion of hydrogen and/or calcium are associated with aggregation. The mycelial growth of fungi appears to have a binding effect on soils.

Although kind of clay and amount of organic matter affects soil structure, there are other factors that also affect soil structure. The following have long been known to improve structure: **freezing and thawing**, **wetting and drying, action of burrowing insects and animals**, and the growth of **root systems of plants**. All of these have a loosening effect on the soil, but it should be kept in mind that they have no part in aggregate stability. The loosening of the soil is a necessary part of aggregate formation, not aggregate stability.

Top 10 Scientific Journals related to Soil Science

1- *Soil Science Society of America Journal (SSSAJ)*
2- *Soil Science*
3- *Journal of Soil Science*
4- *Eurasian Journal of Soil Science*
5- *Indian Journal of Soil Science*
6- *Soil Use and Management*
7- *Geoderma*
8- *Soil & Tillage Research*
9- *Canadian Journal of Soil Science*
10- *Australian Journal of Soil Research*
11- *Transactions of the American Society of Agricultural Engineers (ASAE)*
12- *Catena*