2026

NCF-ENVIROTHON MISSISSIPPI

# STUDY RESOURCES

# SOILS & LAND USE

ENVIROTHON MISSISSIPPI 2026

# 2026

# Soils and Land Use

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*Any hyperlinks included in the study resources, apart from those explicitly listed as Resources on the Key Topics page and featuring a dedicated page in the resources (such as YouTube videos), are considered supplemental material ONLY. While they can provide extra information, they are not mandatory study resources.*

## NCF-Envirothon 2026 Mississippi

# Soils and Land Use Study Resources

**Key Topic #1: Geology**

1. Identify unique geological features of Mississippi.
2. Describe the characteristics of the three major types of rocks (igneous, sedimentary, and metamorphic) and give examples of each.
3. Describe how the rock type of parent material determines what minerals are present in the soil.
4. Explain the importance of different types of weathering (mechanical and chemical) in soil formation.

| Resource Title | Source | Located on Page |
|---|---|---|
| Module 2: Geology and the Foundations of Mississippi Soils | *Mississippi Soils Study Guide for the Mississippi Envirothon** | 4 |

** Mississippi Soils Study Guide for the Mississippi Envirothon:*
*The guide serves as a comprehensive collection of resources and information gathered from multiple academic, scientific, and governmental sources and agencies. Notable contributions include, but are not limited to:*

- *USDA Natural Resources Conservation Service*
- *U.S. Geological Survey (part of the U.S. Department of the Interior)*
- *Mississippi Department of Environmental Quality*
- *Mississippi State University*
- *Other peer-reviewed sources*

**Module 2: Geology and the Foundations of Mississippi Soils**

Introduction

Introduction This module serves as the Geology section of the training manual. It provides the essential background needed to understand why Mississippi soils vary so significantly from the Delta to the Hills. An understanding of the Geologic History—or what we call here "The Big Story"—of the state's formation, provides explanations of the geologic drivers that produced the specific soil properties encountered in the field.

The module is organized to move from continental-scale history to the microscopic chemical reactions that create soil:

- **Section I: The Geologic Drivers** (Tectonics, Climate, and Large-Scale History)
- **Section II: Lithology and Composition** (The Mineral Building Blocks and Rock Types)
- **Section III: Pedogenesis** (The Chemical and Physical Transformation of Parent Material)
- **Section IV: Spatial Synthesis** (Mapping Mississippi's Geologic Provinces)

**Section I: The Geologic Drivers – Tectonics, Climate, and Time**

**A. Tectonic Origins: The Hotspot and the Rift**

Mississippi's journey began with the collapse of the **Mississippi Embayment**. This structural trough formed when the North American plate passed over a volcanic hotspot, causing the crust to bulge and subsequently rift. This event physically severed the once-continuous Appalachian-Ouachita mountain chain, creating the low-lying basin that would eventually dictate the flow of the Mississippi River and the continent's primary river system.

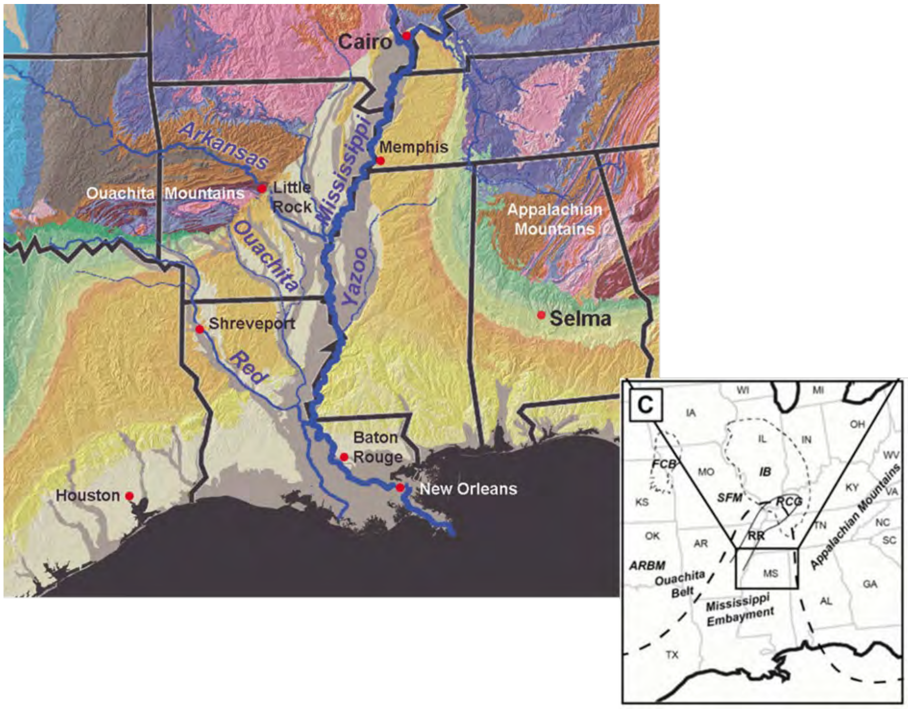



Figure 1.1 The Mississippi Embayment: A structural trough formed by ancient rifting, positioned between the Appalachian and Ouachita highlands. This framework dictated the flow of modern river systems and the deposition of parent materials across the region.

### B. Mineralogical Inheritance of Glacial Rock Flour

A critical component of Mississippi's soil fertility lies in its "mineral ancestry." During the Pleistocene, massive continental glaciers advanced across the northern United States. These glaciers acted as giant conveyor belts, grinding down the **Igneous** (**Granite/Basalt**) and **Metamorphic** (**Gneiss/Schist**) rocks of the Canadian Shield.

- **The Silt Source:** This mechanical grinding produced **"rock flour"—**unweathered silt containing primary minerals like **Feldspar**, **Mica**, and **Quartz**.
- **Climate as a Force:** This illustrates the **Climate** factor of soil formation; cold northern climates provided the physical force to create the materials that Mississippi's warm, humid climate would later chemically weather.

**C.**

**Marine Transgression and Time**

For millions of years, the Embayment was a shallow arm of the Gulf of Mexico. This period of **Marine Transgression** (encroachment) allowed for the deposition of calcium-rich marine sediments.

- **The Stratigraphic Staircase:** As sea levels rose and fell over **Geologic Time**, layers of chalk, marl, and clay were stacked. Because the basin is tilted, these layers are exposed as chronological "bands" across the state, with the oldest exposed in the Northeast.


Figure 1.2 This comparison illustrates the two extremes of Mississippi's geologic history. The Glacial Maximum (left) drove river entrenchment and provided the 'rock flour' that became wind-blown Loess. The Marine Transgression (right) shows a period of high sea levels when the Gulf of Mexico flooded the Embayment, depositing the marine chalks and clays now found in the Blackland Prairie.

**Section II: Lithology and Composition – Minerals and Rocks**

**A. Mineralogical Inheritance**

Soils inherit their chemical potential from their parent rocks. In Mississippi, the primary minerals provided by the "Geologic Drivers" include:

- **Quartz:** Provides structural stability and sand grains.

- **Feldspar:** A source of potassium and calcium; it is highly susceptible to chemical weathering.
- **Apatite:** The primary natural source of phosphorus in the soil.

### B. The Rock Cycle in Mississippi

While the source rocks in the North were Igneous and Metamorphic, Mississippi's bedrock is almost exclusively Sedimentary. These were formed by the lithification of the marine and river sediments discussed in Section I.

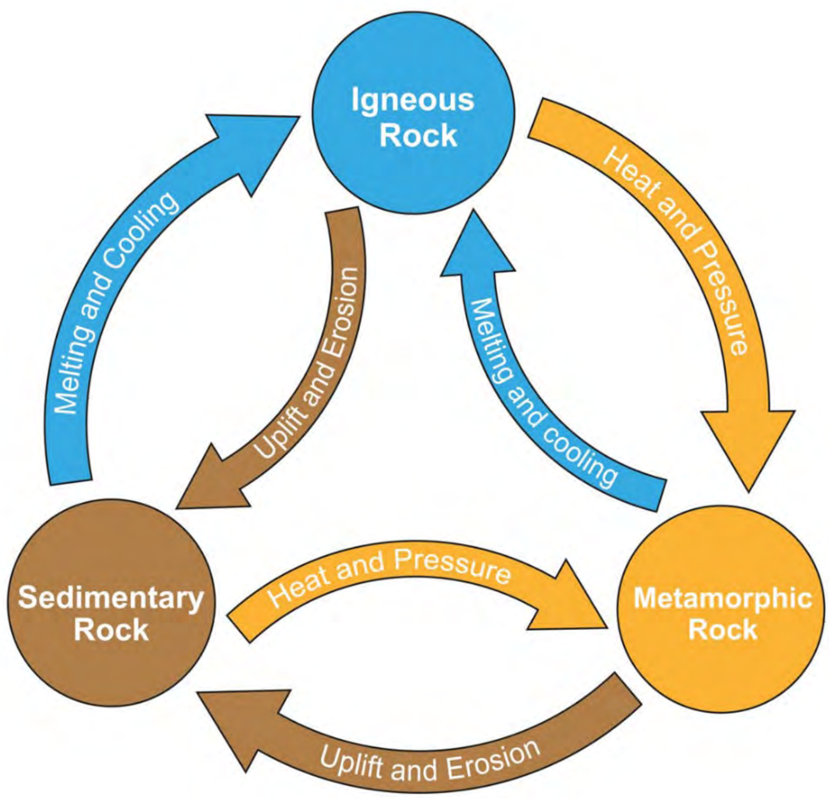



Figure 2.1 The Rock Cycle illustrates how geological materials are recycled over time. In Mississippi, we primarily observe the sedimentary phase: the weathered 'rock flour' and marine sediments from Section I were compacted and cemented (lithified) to form the state's limestone, sandstone, and chalk bedrock.

### C. The Mineral Weathering Sequence

Not all minerals are created equal in their resistance to weathering. The order in which minerals break down at the Earth's surface is generally the inverse of the order in which they formed, a concept known as Bowen's Reaction Series.

- **Thermal Disequilibrium:** Minerals that form at extremely high temperatures, such as **Olivine**, are the most "unhappy" and unstable when exposed to Mississippi's cool, humid surface environment; they weather most rapidly.
- **Stable Minerals: Quartz** forms at much lower temperatures and is the most resistant mineral to chemical attack. This explains why Quartz remains the dominant mineral in Mississippi's most ancient soil profiles.
- **The Stability Timeline:** The stability of a mineral is often measured by the time required to dissolve it. While it may take only a few thousand years to dissolve high-temperature minerals, it can take tens of millions of years to dissolve Quartz.

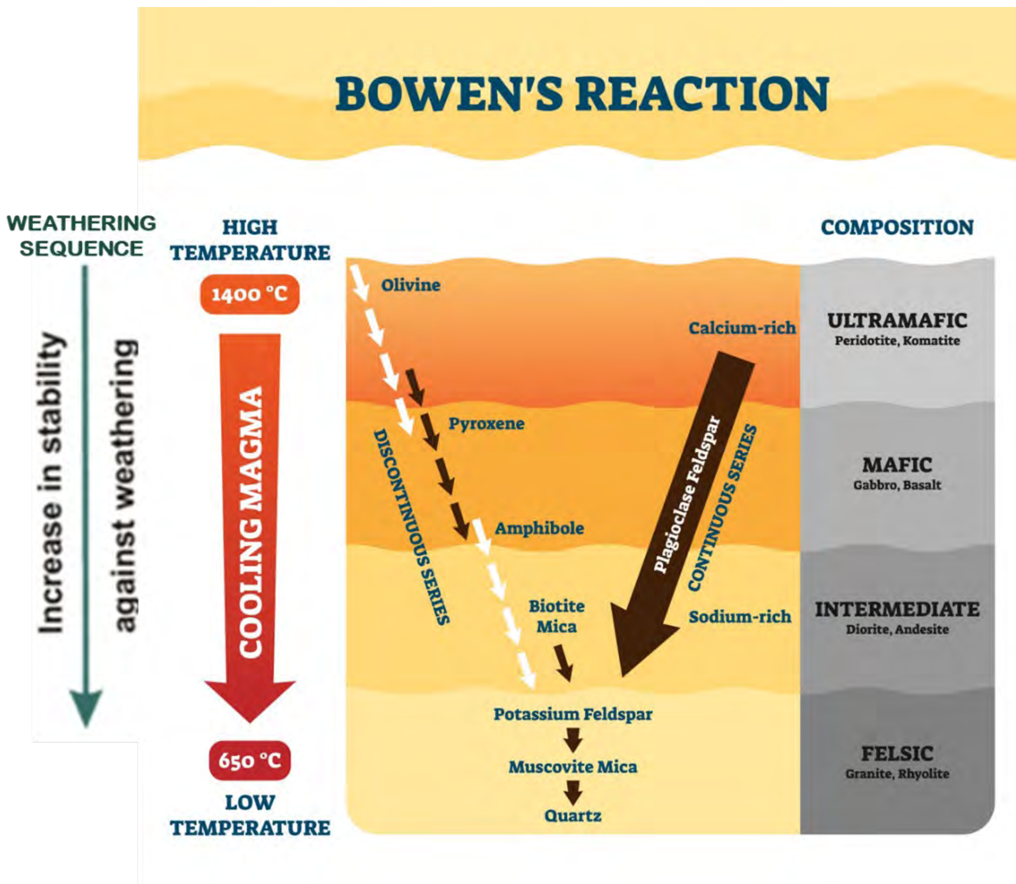



Figure 2.2 The Weathering Sequence: These diagrams illustrate mineral stability. Minerals at the top of the series (Olivine) weather rapidly, while those at the bottom (Quartz) are highly resistant and persist in the soil for millions of years.

## Section III: Pedogenesis – The Transformation

### A. Physical vs. Chemical Weathering

- **Physical Weathering:** In our "Big Story," the glaciers provided the primary physical weathering (grinding) in the northern source areas.
- **Chemical Weathering:** In Mississippi's warm, humid environment, chemical weathering is the dominant process for soil development.

### B. The Biogeochemical Toolkit

**Hydrolysis: Hydrolysis:** This is the reaction between mineral grains and water. In this process, water ($H_2O$) slightly dissociates into $H^+$ and $OH^-$ ions. The $H^+$ ions attack the crystal structure of primary minerals like **Feldspar**, replacing the potassium, or calcium ions when present. This chemical exchange results in the structural collapse of the mineral into **Kaolinite Clay** and the release of dissolved nutrients into the soil solution.


Potassium feldspar + hydrogen ions + water → kaolinite + potassium ions + silica

$$2KALSi_3O_8 + 2H^+ + H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 2K^+ + 4SiO_2$$

Figure 3.1 Hydrolysis: The chemical breakdown of Feldspar by water and carbonic acid, resulting in the formation of clay minerals and the release of essential plant nutrients.

- **Carbonation:** Rainfall mixing with $\boldsymbol{CO_2}$ to form weak carbonic acid, which dissolves the **Marine Chalk** of the Blackland Prairie.

- **Oxidation/Reduction (Redox):** This process creates the "red/yellow" colors in many of Mississippi's highly weathered soils (Oxidation) or "gray/blue" mottling in wet Delta soils (Reduction).

## Section IV: Spatial Synthesis – Mapping Mississippi's Geologic Provinces

### A. The Surface Geology Map

The Surface Geology Map of Mississippi is the visual proof of the "Big Story".

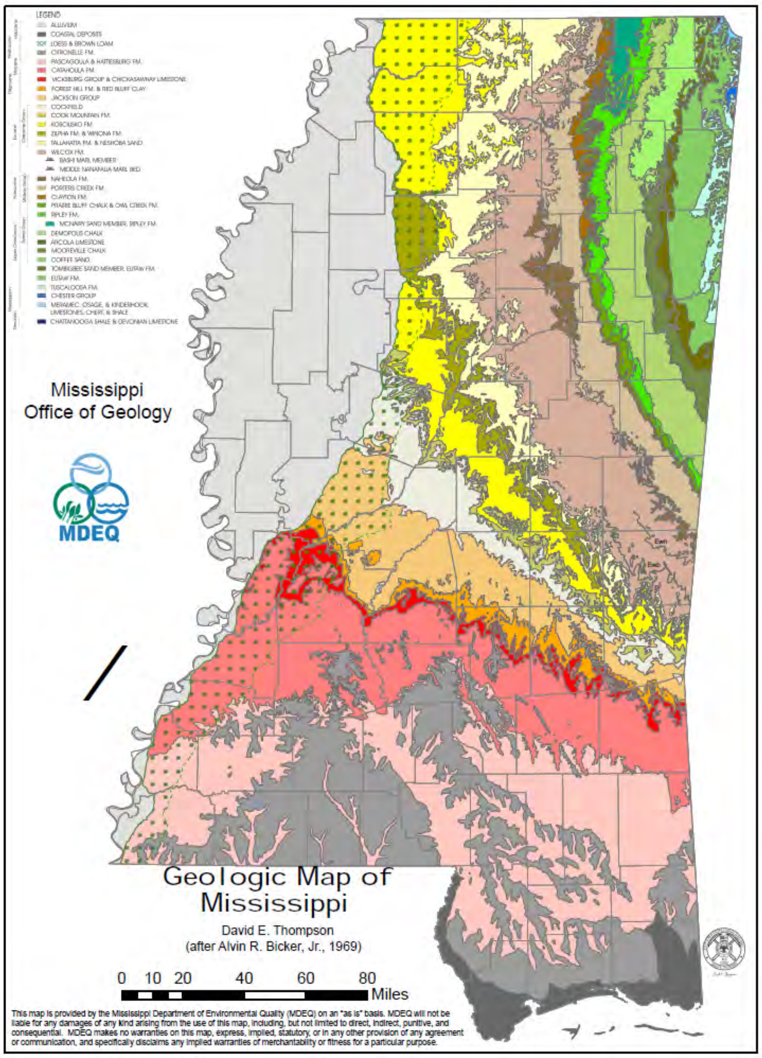



Figure 4.1 The Surface Geology Map serves as a chronological record of the state. The tilted bands of color, indicative of stratigraphy and uplift, represent different geologic units, such as the Wilcox and Claiborne groups, which act as the parent materials for modern soils. The wide gray area in the west marks the Alluvial Plain (The Delta), where the Mississippi River deposited its fertile sediments. And the stippled area running alongside the Alluvial Plain from north to southwest, represents Mississippi Valley Loess.

**B. The Stability Connection**

The Stability Connection: Linking the Sequence to the Map
By synthesizing the Weathering Sequence with "The Big Story," we can see a clear weathering gradient across the MLRA map:

- **Young/Least Weathered:** The **Mississippi River Alluvium (MLRA 131A)** contains "fresh" minerals that have only recently been deposited[6]. These soils are high on the mineral stability scale and remain nutrient-rich.
- **Intermediate:** The **Loess Belt (MLRA 134)** consists of wind-blown silt that has begun to move down the weathering sequence but still retains significant chemical potential[7].
- **Old/Most Weathered:** The **Coastal Plain (MLRA 133C)** represents the end-stage of the weathering sequence[888]. Because these landforms are ancient, most minerals have dissolved, leaving behind a landscape dominated by highly stable Quartz sand and Kaolinite clay.

**C. Conclusion: The Path to the Major Land Resource Area (MLRA) Map of Mississippi**

- **Mississippi River Alluvium (MLRA 131A):** These plains form as rivers meander and deposit material, gradually building up the land, with the floodplain being the active area within the larger alluvial plain.
- **Southern Mississippi Valley Loess (MLRA 134):** The narrow strip east of the Delta represents the wind-blown "cap" of northern silt.
- **Alabama and Mississippi Blackland Prairie (MLRA 135A), Gulf Coastal Plain (MLRA 133C), Eastern Gulf Coast Flatwoods (MLRA 152A), and Gulf Coast Marsh (MLRA 151):** These are the results of marine transgressions and the stratigraphic staircase. The retreat of the sea lead to older marine sediments in the northeast decreasing in age toward the south. Surface elevation mirrors this pattern, reaching its peak in the northeast and decreasing steadily toward sea level at the southern coast.

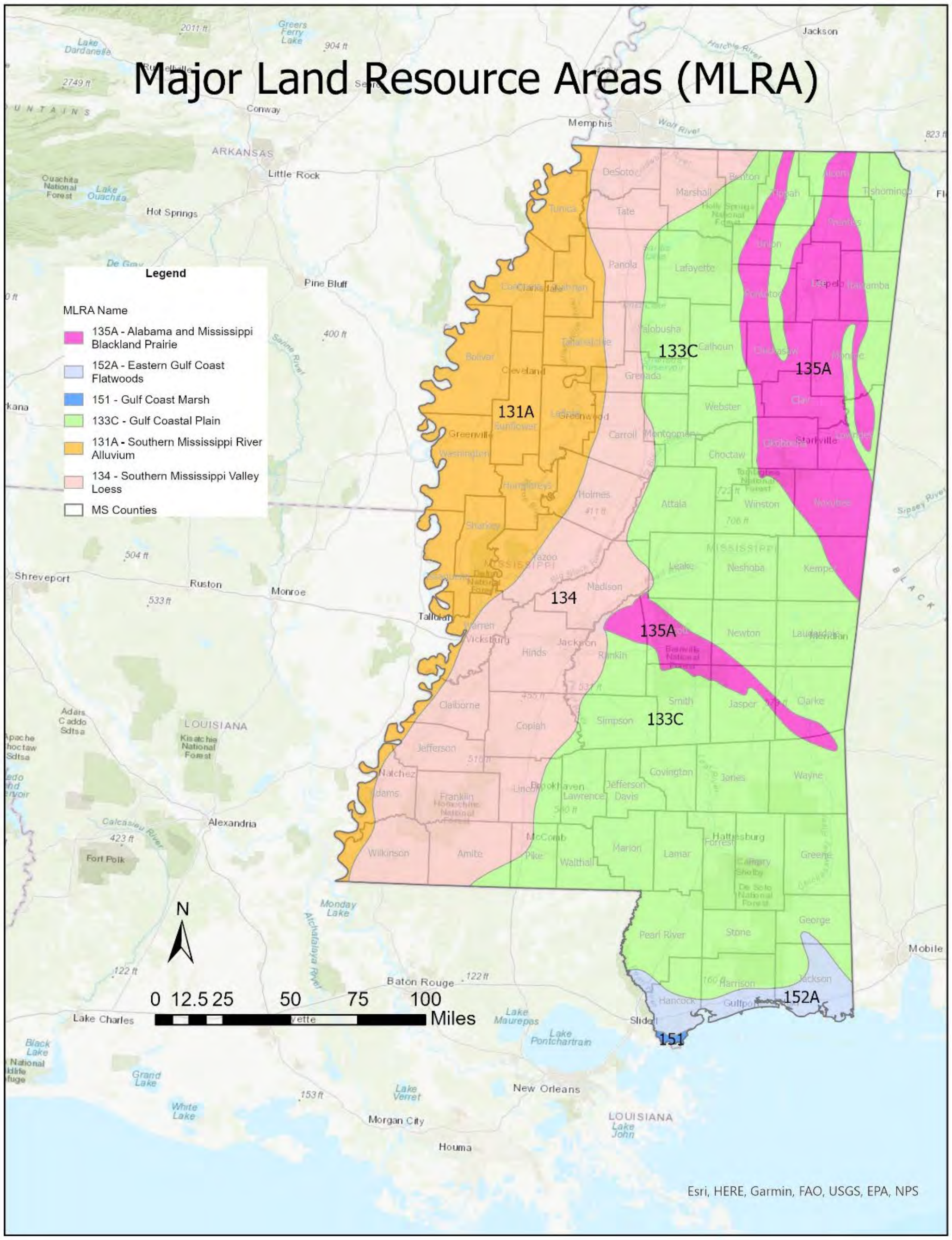



Figure 4.2 The Major Land Resource Area (MLRA) map is the practical result of the geologic drivers discussed in this module. By matching this map with the Surface Geology map, the geology can be traced to MLRA's, e.g., the ancient marine floors became the Coastal Plain and Blackland Prairie and glacial dust became the Mississippi Valley Loess.

By synthesizing Geologic History, Mineral Source, and Weathering Processes, we arrive at the Major Land Resource Areas (MLRAs). Understanding geology helps to interpret how the interdependencies of the Soil Forming Factors are revealed by the properties observed in a soil profile.

**NCF-Envirothon 2026 Mississippi**

## Soils and Land Use Study Resources

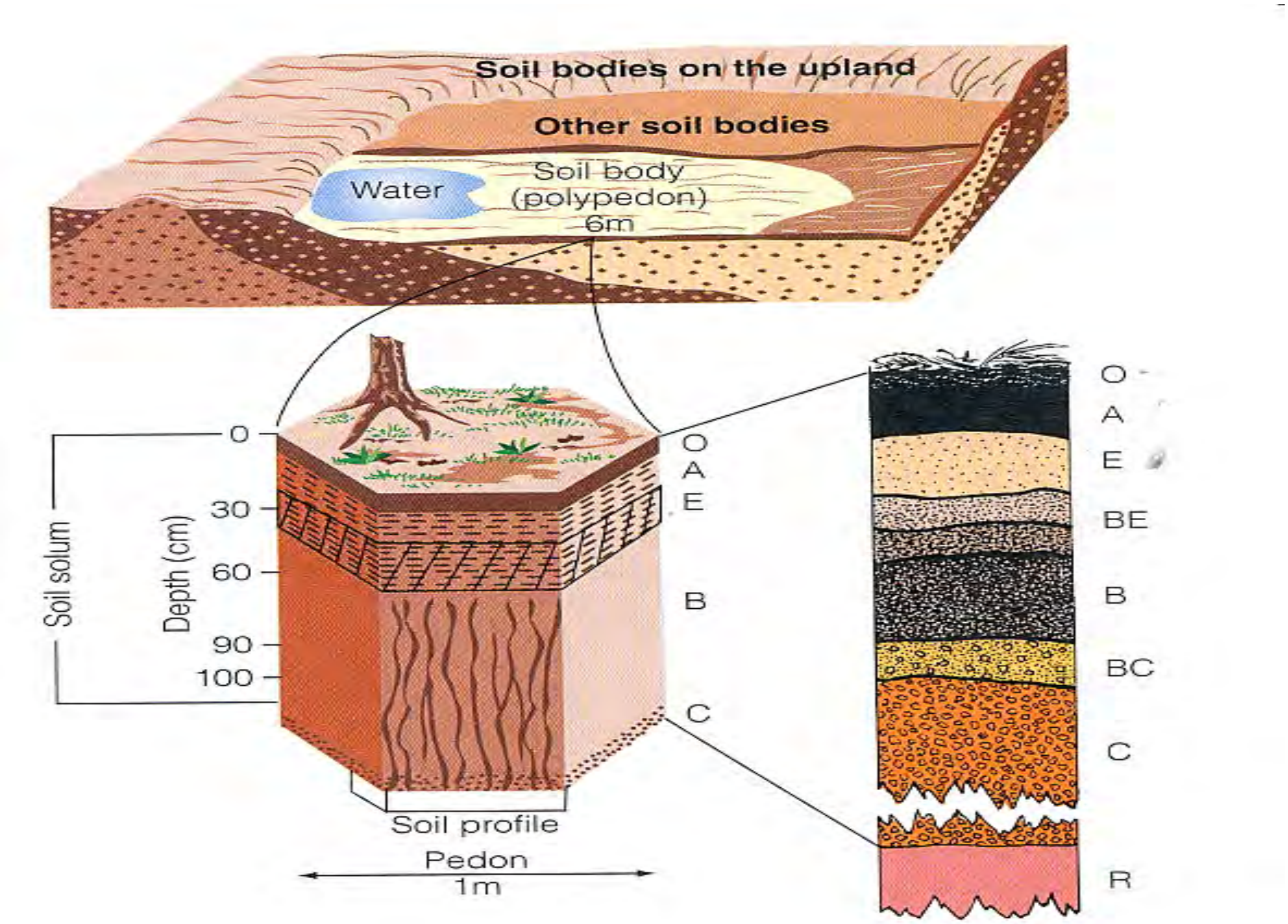
**Key Topic #2: Soil Structure and Formation**

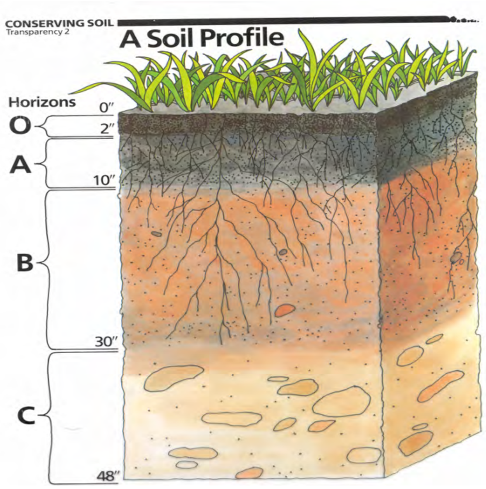
5. Define the five soil-forming factors and describe their influence on a particular soil.
6. Describe the characteristics of the major soil orders.
7. Describe how different soil components (mineral composition, organic matter, particle size, etc.) affect the properties of a soil.
8. Analyze soil processes as they relate to observed soil characteristics.
9. Describe the importance of organic matter in various forms (humus, litter, et cetera) to soil health, structure, and fertility.

| **Resource Title** | **Source** | **Located on Page** |
|---|---|---|
| Soil Formation, Chapter 2 | *Mississippi Soils Study Guide for the Mississippi Envirothon** | 14 |
| Soil Properties: Physical and Chemical, Chapter 3 | *Mississippi Soils Study Guide for the Mississippi Envirothon** | 29 |
| 12 Orders of Soil Taxonomy Poster | *Poster. (2022). Twelve Orders of Soil Taxonomy. USDA NRCS. https://www.nrcs.usda.gov/sites/default/files/2022-06/orders_hi.pdf* | 68 |
| Healthy Soil Are: factsheet | *Fact Sheet. (2023). USDA NRCS. https://www.nrcs.usda.gov/sites/default/files/2023-01/Healthy-Soils-Are-full-of-life.pdf* | 71 |

# Chapter 2: Soil Formation

## Soil and Its Setting




**Soil profile and its layers (horizons):**

- Soil scientists often dig a large hole, or soil pit, to expose the soil for study.
- **Soil profile**: the vertical section exposing the soil through all its horizons are seen.
- **Horizons:** (layers of soil) A soil layer that is nearly parallel to the land surface and is different from other layers above and below it is called a soil horizon. Horizons vary in thickness.
- **Weathering** first starts at the surface, and works its way down, the uppermost layers have been changed the most, while the deepest layers are most similar to the original unconsolidated soil material, which is called **parent material.**

**Horizons:** In some soil profiles, the horizons are very distinct in color, or texture. In others, the changes are so gradual that the horizons are difficult to distinguish.

- O horizon: top horizon of original organic matter accumulation; darker colored soil;
- A horizon: organic-matter-enriched horizon near or at the soil surface; darker color; region of intense weathering. Also known as **topsoil.**
- E horizon: layer (in some soils) just below the A horizon that has not accumulated organic matter, and is intensely weathered and **leached** (removal of materials in solution from the soil by percolating water). Also known as **subsurface**.
- B horizon: underlying the A and O horizons; contain less organic matter than horizons near surface; varying amounts of clays, iron and aluminum oxides, gypsum, or calcium carbonate may accumulate here, or may have been formed in place through the weathering process. Also known as **subsoil.**
- C horizon: least weathered part of the soil profile; plant roots and microorganisms extend into this horizon. Also known as **parent material**.

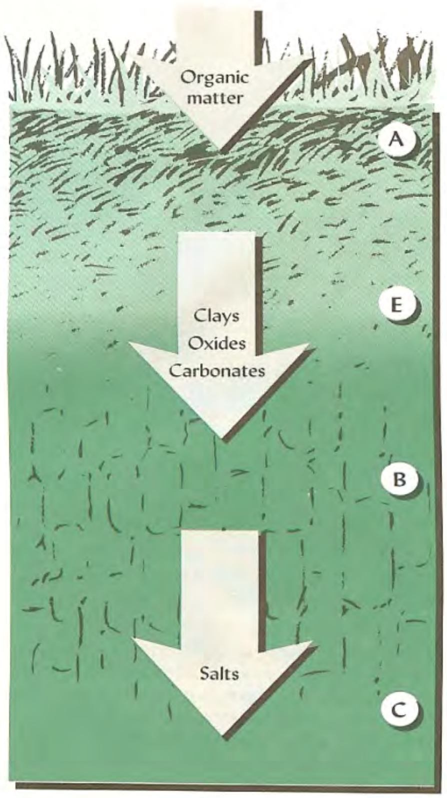



**FIGURE 1.12** Horizons begin to differentiate as materials are added to the upper part of the profile and other materials are translocated to deeper zones. Under certain conditions, usually associated with forest vegetation and high rainfall, a leached E horizon forms between organic-matter-rich A and the B horizons. If sufficient rainfall occurs, soluble salts will be carried below the soil profile, perhaps all the way to the groundwater.

(from: Brady and Weil Nature and Property of Soils,12th ed. 1999)

Photo 8.—An ochric epipedon from an Oxisol in Hawaii. The ochric epipedon has high value and chroma.

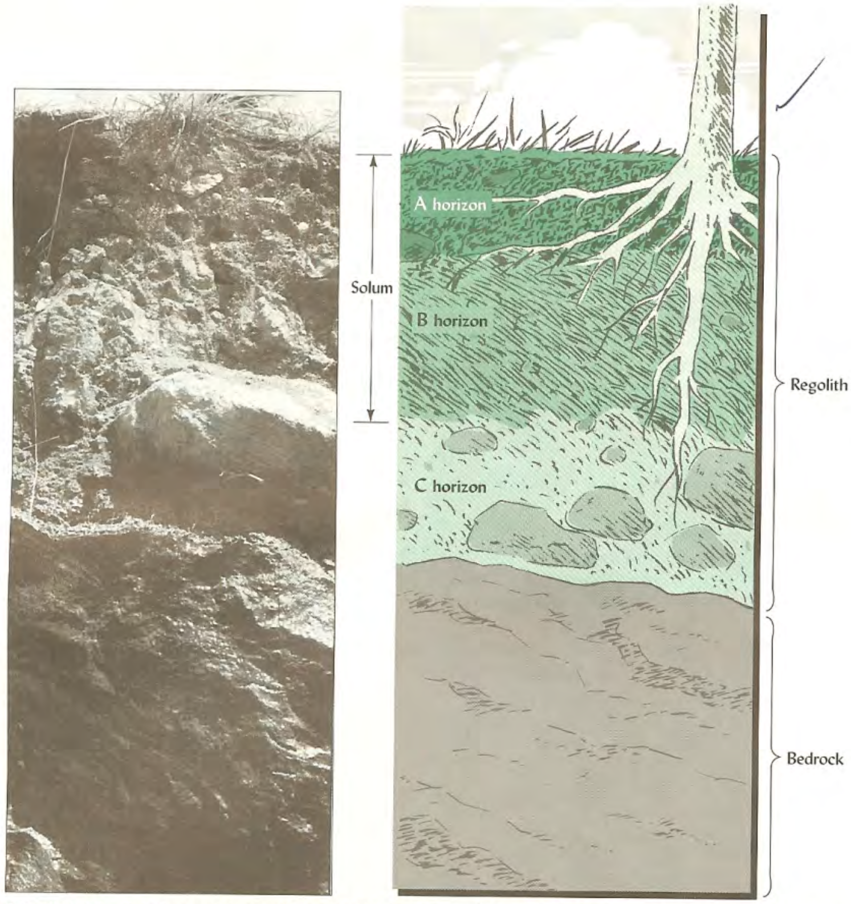


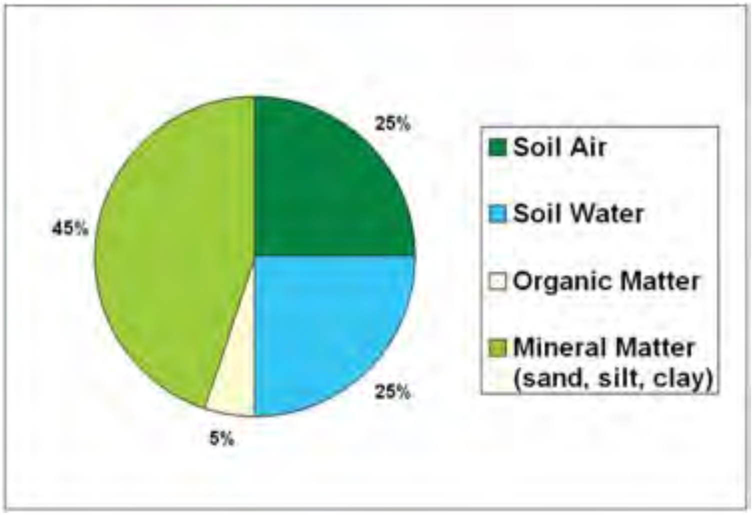

FIGURE 1.10 Relative positions of the regolith, its soil, and the underlying bedrock. Note that the soil is a part of the regolith, and that the A and B horizons are part of the **solum** (from the Latin word *solum,* which means soil or land). The C horizon is the part of the regolith that underlies the solum, but may be slowly changing into soil in its upper parts. Sometimes the regolith is so thin that it has been changed entirely to soil; in such a case, soil rests directly on the bedrock. (Photo courtesy of R. Weil)

(from: Brady and Weil Nature and Property of Soils, 12th ed. 1999)

**Soil Properties** – delineation of the horizons present in the soil profile requires careful examination, using your senses as well as your brain. In addition to seeing colors, a soil scientist may feel, smell, and listen to the soil, as well as conduct chemical tests, in order to distinguish and describe the horizons present.

**Components of Soil** –

- 4 major components: 1) air, 2) water, 3) mineral matter, and 4) organic matter
- Relative proportions of these 4 components greatly influence the behavior and productivity of soils
- On a volume basis all soils have some composition of these components. Their variation is a direct reflection of how, where, when and under what conditions the particular soil formed in place.
  - This variation may cause the soil either to be a mineral soil (having more than 80% of mineral matter; or to be an organic soil (having more than 20% of organic matter).
  - On the average a soil contains 45% Mineral matter, 25% Water, 25% Air, and 5% Organic Matter.
  - These components are mixed so intimately in the entire soil that it is hard to separate them. These components, if they were separated, the soil's properties will be lost completely, as soil will lose its identity as a dynamic living body in nature.



**Composition of a natural soil, by weight.**

**Soil Formation**

Weathering of Rocks and Minerals (Parent Material)

**Weathering** – The physical and chemical breakdown of rocks and minerals into smaller particles. The properties of the rocks and minerals help to determine the rates of weathering.

**Physical Weathering** (decomposition)

**Temperature** – heating and cooling of rocks over time causes alternate expansion and contraction of the minerals in the rocks. This puts stress on the rock, and it eventually cracks and breaks apart. Temperature also controls the rate of chemical action in weathering.

**Abrasion by water, ice, and wind** – water and ice have tremendous cutting, grinding, and moving power. Windblown sand and dust can wear away rocks as well (think of it as another type of "sandblasting"

**Plants and animals (biota)** – burrowing animals and growing plant roots enter cracks, forcing rocks further apart. Living organisms also recycle nutrients through the soil. Humans exert influence through dirt-moving and construction. Biota is not as much of an initial influence of physical weathering as water, wind, ice, and temperature change.

**Chemical Weathering** (disintegration)

- Most intense in hot, humid environments
- Enhanced by water, oxygen, and the organic and inorganic acid by-products that result from biological and previous chemical activities.

**Hydrolysis and dissolution –** water molecules solubilize minerals in the rock. These solubles can then be transported as the water drains through the layers of soil and rock.

**Oxidation and Reduction** (redox) **Reaction –** when minerals that contain iron, manganese, or sulfur are exposed to oxygen and water during soil formation, they experience alternating oxidation and reduction reactions.

Chemical equation: $\overset{2^{+}}{2FeO} + 2H_2O \leftrightarrow \overset{3^{+}}{2FeOOH} + 2H^{+} + 2e^{-}$

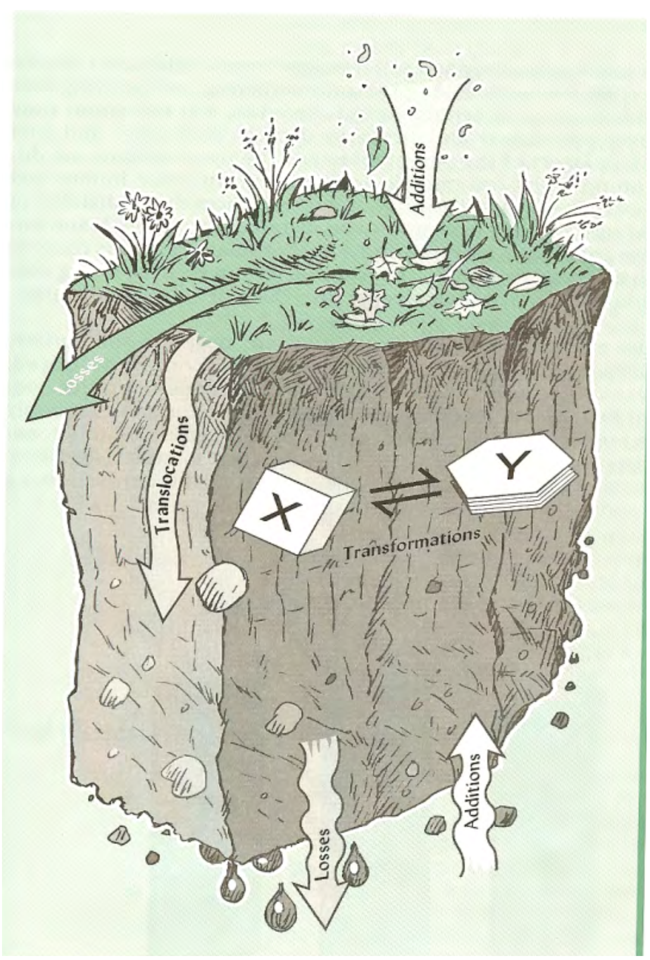
Fe (II) Fe(III)

Loses electron gives off $H^{+}$ ions

Oxidation – soil is well-aerated (oxygenated), oxidation state is $Fe^{3+}$ (FeOOH)

Reduction – soil is poorly aerated (less oxygen, more water, saturated conditions), Reduced state is $Fe^{2+}$ (FeO)

Together, physical and chemical weathering throughout the landscape over time break down rocks and minerals into smaller particles of clay, sand, and silt; and also they release mineral nutrients (P, K, Ca, Mg, Fe, S, Mn, etc) that are essential for plant growth.



## 5 Factors of Soil Formation

1. **Parent material** – geological or organic precursors to the soil
2. **Climate** – primarily precipitation and temperature
3. **Biota** – living organisms, native vegetation, microbes, soil animals, & humans
4. **Topography** – slope, aspect, and landscape position
5. **Time** – period of time since parent materials became exposed to soil formation

Easy acronym to remember:
CLORPT (Climate, Living Organism, Relief, Parent material, Time)

## Parent Material

- Parent material refers to the great variety of unconsolidated organic material (such as fresh peat) and mineral material in which soil formation begins.
- Mineral material includes partially weathered rock; ash from volcanoes; sediments moved and deposited by wind, water, or gravity; and ground-up rock deposited by glacial ice.
- The material has a strong effect on the type of soil that forms and the rate at which it forms.
- Soil formation may take place more quickly in materials that are more permeable to water. Dense, massive, clayey materials can be resistant to the processes of soil formation. In soils that formed in sandy material, the A horizon may be a little darker than its parent material, but the B horizon tends to have a similar color, texture, and chemical composition.

### Classification of Parent Material

| | |
|---|---|
| 1. Formed in place | Residual |
| 2. Transported | |
| By gravity | Colluvial |
| By water | |
| Rivers and streams | Alluvial |
| Oceans | Marine |
| Lakes | Lacustrine |
| By ice | Glacial |
| By wind | Eolian |
| 3. Accumulated plant and animal debris | Organic |

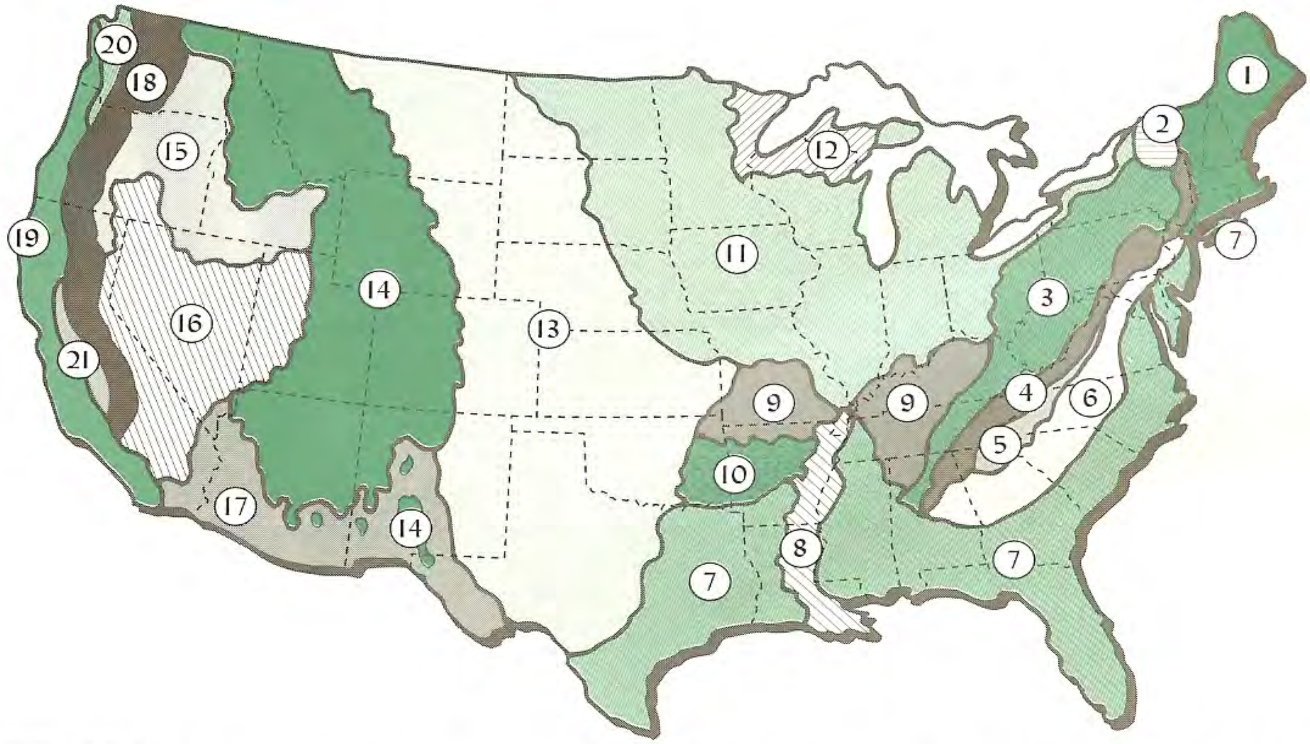



**FIGURE 2.11** Generalized physiographic and regolith map of the United States. The regions are as follows (major residual areas italicized).

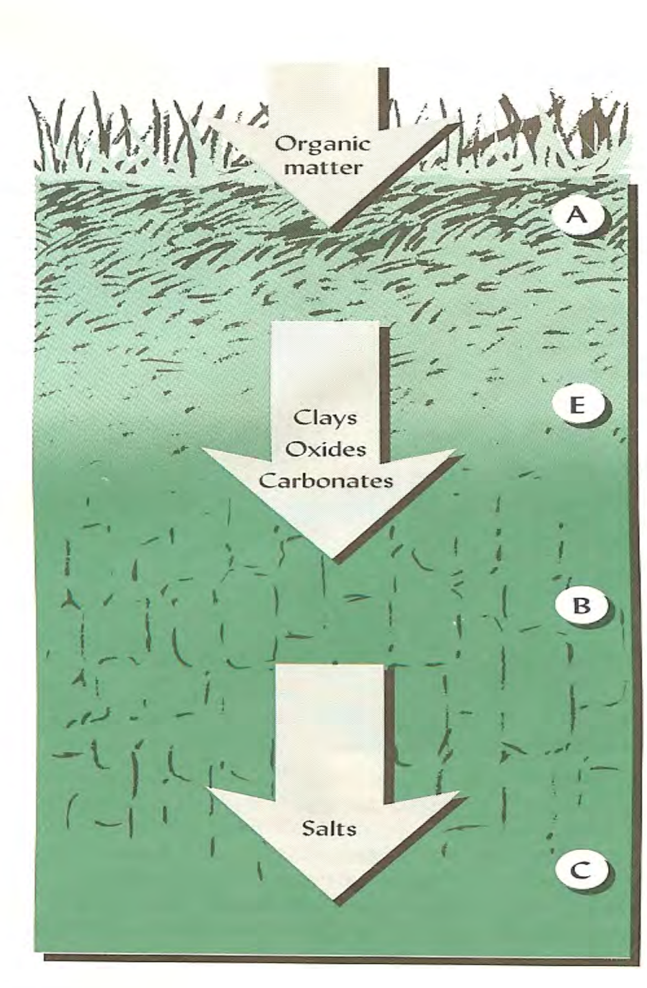
1. New England: mostly glaciated metamorphic rocks.
2. Adirondacks: glaciated metamorphic and sedimentary rocks.
3. *Appalachian Mountains and plateaus:* shales and sandstones.
4. *Limestone valleys and ridges:* mostly limestone.
5. Blue Ridge mountains: sandstones and shales.
6. *Piedmont Plateau:* metamorphic rocks.
7. Atlantic and Gulf coastal plain: sedimentary rocks with sands, clays, and limestones.
8. Mississippi floodplain and delta: alluvium.
9. *Limestone uplands:* mostly limestone and shale.
10. *Sandstone uplands:* mostly sandstone and shale.
11. Central lowlands: mostly glaciated sedimentary rocks with till and loess, a wind deposit of great agricultural importance (see Figure 2.17).
12. Superior uplands: glaciated metamorphic and sedimentary rocks.
13. *Great Plains region:* sedimentary rocks.
14. *Rocky Mountain region:* sedimentary, metamorphic, and igneous rocks.
15. Northwest intermountain: mostly igneous rocks; loess in Columbia and Snake river basins (see Figure 2.21).
16. Great Basin: gravels, sands, alluvial fans from various rocks; igneous and sedimentary rocks.
17. Southwest arid region: gravel, sand, and other debris of desert and mountain.
18. *Sierra Nevada and Cascade mountains:* igneous and volcanic rocks.
19. *Pacific Coast province:* mostly sedimentary rocks.
20. Puget Sound lowlands: glaciated sedimentary.
21. California central valley: alluvium and outwash.

(from: Brady and Weil Nature and Property of Soils,12th ed. 1999)

**<u>Climate</u>** – most influential acting on parent material because it determines nature (physical, chemical, or both) and intensity of weathering that occurs over large geographic areas. Climate is a major factor in determining the kind of plant and animal life on and in the soil. It determines the amount of water available for weathering minerals and for transporting the minerals and elements released.

**Precipitation** - *WATER*

- The greater the rainfall amount, the more rapid the rate of both weathering and erosion.
- Rainfall causes leaching. Rain dissolves some minerals, such as carbonates, and transports them deeper into the soil. The greater the depth of water penetration into the soil, the greater the depth of weathering soil and development.
- Water transports soluble and suspended materials from upper to lower layers.
- Water stimulates weathering reactions.
- Lack of water in soils in dry regions is influential as well.
- Soluble salts are not transported through soil; instead they will build up and hurt plant growth.



**Temperature**

- For every 10°C rise in temperature, the rates of biological and chemical reactions more than double. Temperature rise and increased moisture accelerate organic-matter decomposition. The opposite is true for cold, dry climates.

- Temperature variations are influential in the breaking down of rocks. Under the control of climate, freezing, thawing, wetting, and drying break parent material apart.

- Influences types of natural vegetation – trees, grass, and/or shrubs. Warm, moist climates encourage rapid plant growth and thus high organic-matter production.

- Climate exerts its influence through the biota factor.

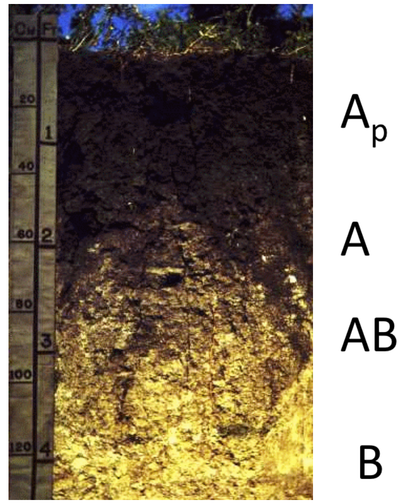
**Biota: Living Organisms -** Organic matter accumulation, biochemical weathering, profile mixing, nutrient cycling, and soil structure are all enhanced by activities of organisms in the soil.

**Effects of Vegetation**:

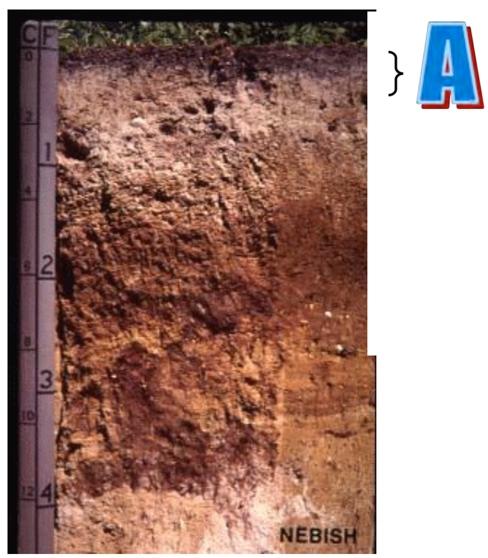
- Vegetative cover reduces erosion rates, slowing down rate of mineral surface soil removal.
- Soil formation and organic matter additions; nutrient cycling from lower to upper layers
  - Leaves, twigs, and bark from large plants fall onto the soil and are broken down by fungi, bacteria, insects, earthworms, and burrowing animals.
  - These organisms eat and break down organic matter, releasing plant nutrients. Some change certain elements, such as sulfur and nitrogen, into usable forms for plants.
  - Microscopic organisms and the humus they produce act as a kind of glue, holding soil particles together in aggregates.
- Different types of vegetation form different types of soil horizons
  - In general, deep-rooted plants contribute more to soil formation than shallow-rooted plants because the passages they create allow greater water movement, which in turn aids in leaching.

  - EXAMPLE: grasslands: organic matter added to soil is from deep fibrous grass roots system; creates thick dark-colored A horizon
  - EXAMPLE: forestland: tree leaves on forest floor build up as organic matter, but the A horizon is much thinner and usually not as dark in color.

Prairie system


Forestland system



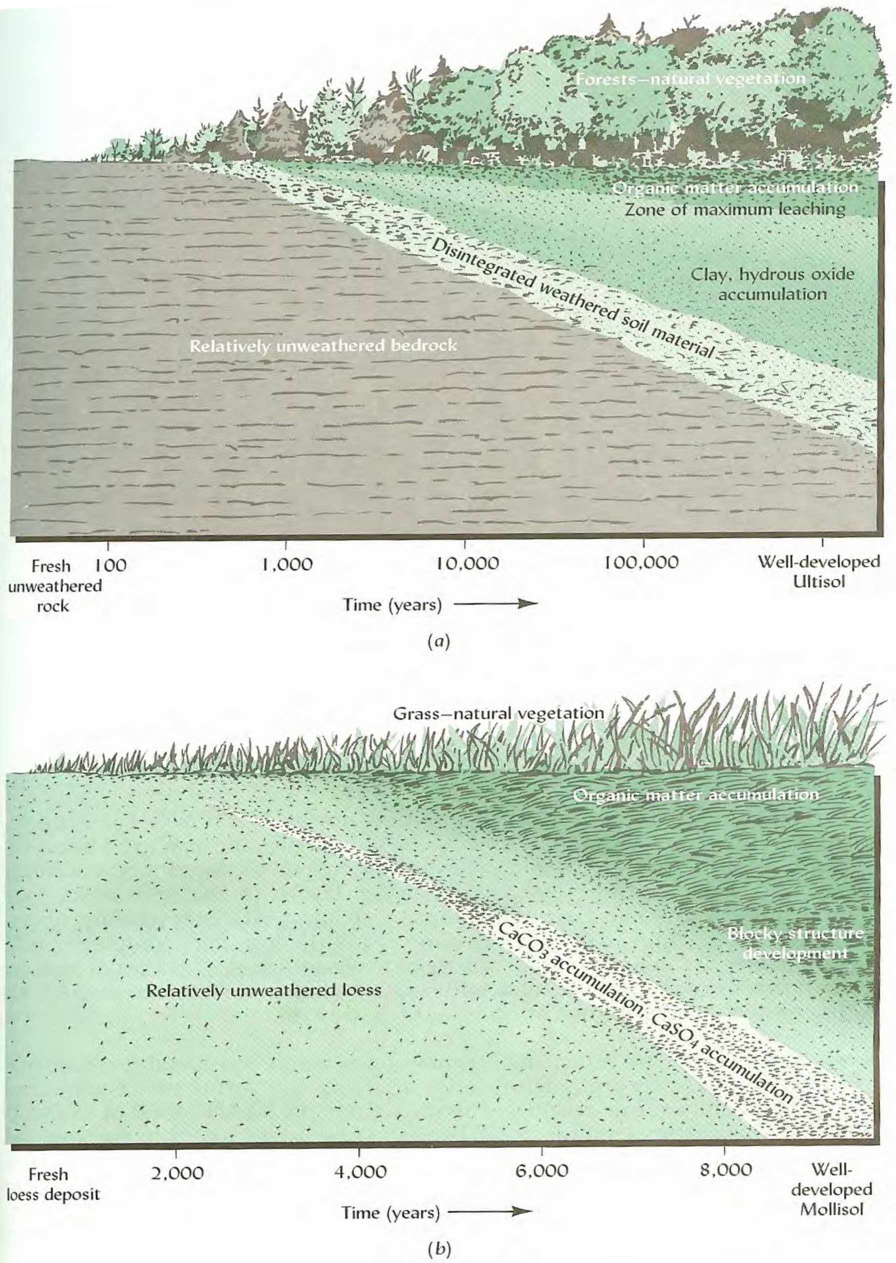



FIGURE 2.26 How two soil profiles may have developed in climatic areas that encouraged as natural vegetation either (*a*) forests or (*b*) grasslands. Organic matter accumulation in the upper horizons occurs in time, the amount and distribution depending on the type of natural vegetation present. Clay and iron oxide accumulate and characteristic structures develop in the lower horizons. The end products differ markedly from the soil materials from which they formed. Note that the time scales for soil development differ markedly for the two parent materials.

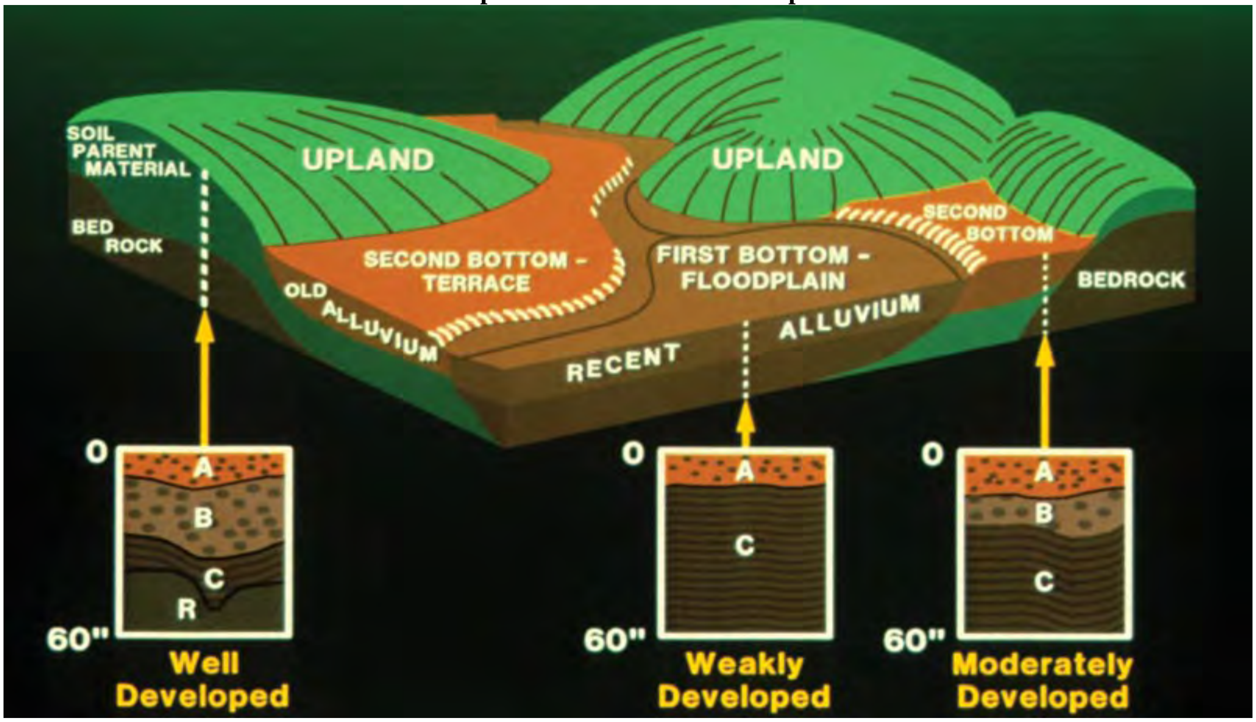
(from: Brady and Weil Nature and Property of Soils,12th ed. 1999)

**Effects of Animals:**

- Large animals (gophers, moles, etc) bore into lower horizons, creating large tunnels and bringing material to the surface. Tunnels allow air and water into the subsurface.
- Earthworms and smaller animals mix a considerable amount of soil, allowing air and water into soil pores.
- Human influence: tillage, irrigation, controlled burning, bulldozers moving, mixing, and leveling tons of earth, flood control.

**Topography (or relief)** – relates to the configuration of the land surface; described in terms of differences in elevation, slope, and landscape position

**Landscape Position and Soil Development**




- Can speed up or slow down the work of climatic forces
- Steep slopes encourage runoff and erosion of surface layers, thus preventing soil formation from getting very far ahead of soil destruction. Steep slopes also have less water infiltration, which reduces the influence of water on soil development deeper in the profile.
  - Creates shallow, poorly differentiated soil profiles
- Interacts with vegetation factor
- Interacts with parent material factor

**Slope Position and Soil Development**

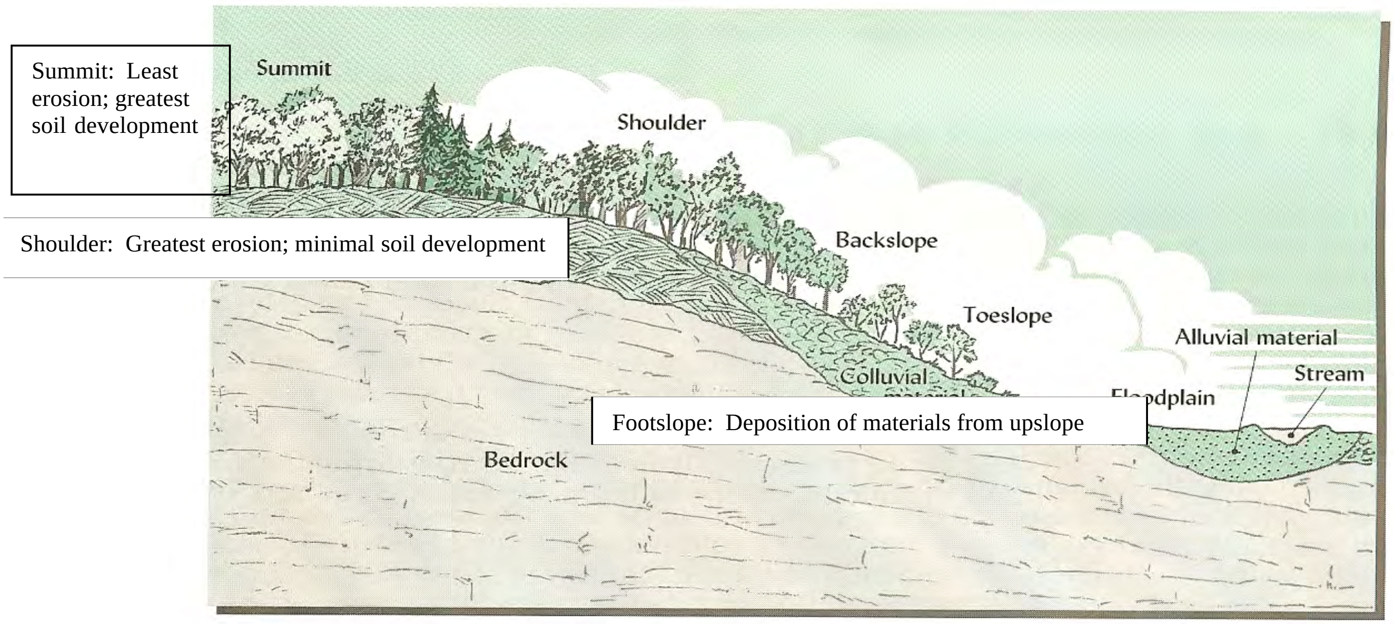



FIGURE 2.31 An interaction of topography and parent material as factors of soil formation. The soils on the summit, toe-slope, and floodplain in this idealized landscape have formed from residual, colluvial, and alluvial parent materials, respectively.

(from: Brady and Weil Nature and Property of Soils,12th ed. 1999)

- Slope aspect- affects the absorbance of solar energy
  - South-facing slopes are more perpendicular to sun's rays and generally warmer, lower moisture content, lower organic matter, and not so deeply weathered as other north, east, or west-facing slopes.
  - North-facing slopes are cooler and wetter with thicker, deeper A and B horizons.

**Slope Aspect and Soil Development**

**<u>Time</u>** – soil-forming processes take time to show their effects.

- The longer a soil surface has been exposed to soil-forming agents, such as rain and growing plants, the greater the development of the soil profile.

- The clock of soil formation starts ticking when a landslide exposes new rock to the weathering environment at the surface, when a flooding river deposits a new layer of sediment on its floodplain, when a glacier melts and dumps its load of mineral debris, or when a bulldozer cuts and fills a landscape to level a construction site or mine-reclamation site.

- Soils in areas of recent alluvial or windblown material and soils on steep slopes where erosion has been active may show very little evidence of horizon development.

- Rates of weathering – anywhere from a few decades to hundreds of thousands of years.
- "Young" or "mature" soil – not so much referring to "age of soil" in years, as to the degree of weathering and profile development.
    - Soils on the older, stable surfaces generally have well defined horizons because the rate of soil formation has exceeded the rate of geologic erosion or deposition.
    - As soils age, many original minerals are destroyed. Many new ones are formed. Soils become more leached, more acid, and more clayey. In many well drained soils, the B horizons tend to become redder as iron accumulates with time.

- Interacts with all other soil forming factors.

# Chapter 3 Soil Properties: Physical and Chemical

**Basic Physical Soil Properties**

A. Color
B. Texture
C. Structure
 C.1. Bulk Density
 C.2. Porosity
 C.3 Permeability
  C.3.1 Cracks
  C.3. 2 Surface Crusts
  C.3.3 Drainage

**Basic Chemical Properties**

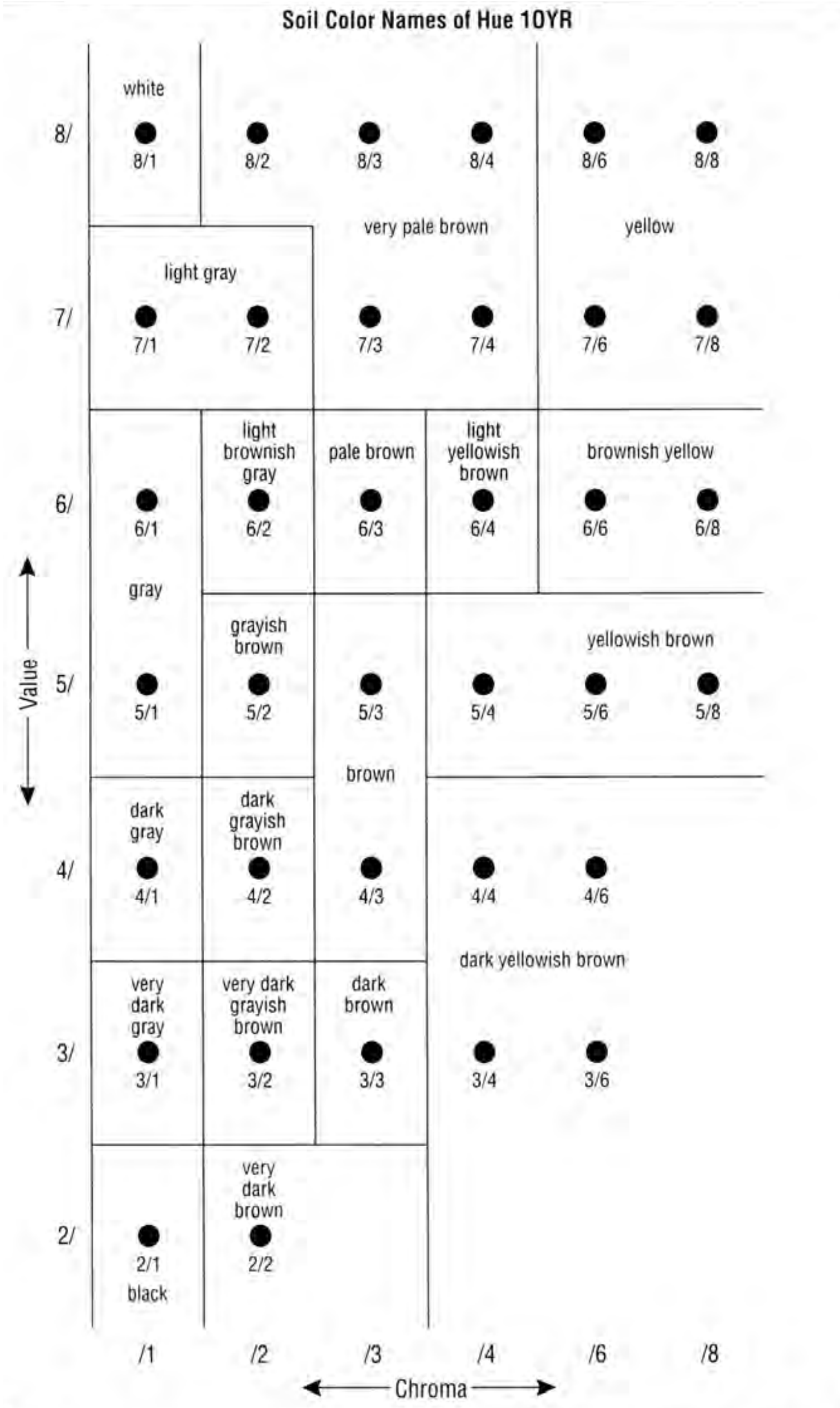
D. pH
E. Cation Exchange Capacity

## A. Soil Color

- Use: Provides valuable clues to the nature of other soil properties and conditions
- Determination: Munsell soil color charts – standard color description system

How to Use the Munsell color chart to know soil color:

- A small piece of soil is compared to standard color chips
- *Munsell notation* is obtained by comparison with a Munsell system color chart. The figures below illustrates the arrangements of color chips for the 10YR Munsell color card.
- The Munsell color system uses three elements of color—*hue, value,* and *chroma*—to make up a color notation. The notation is recorded in the form: hue, value/chroma—for example, 5Y 6/3.

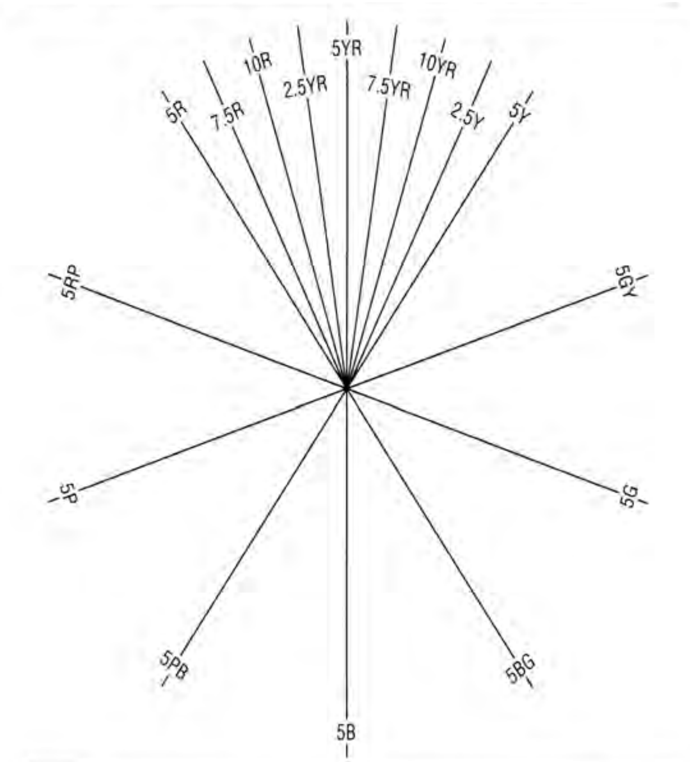



The arrangement of color chips according to value and chroma on the soil-color card of 10YR hue.

- ***Hue*** is a measure of the chromatic composition of light that reaches the eye. The Munsell system is based on five principal hues: red (R), yellow (Y), green (G), blue (B), and purple (P). In the figure below, five intermediate hues representing midpoints between each pair of principal hues, these are yellow-red (YR), green-yellow (GY), blue-green (BG), purple-blue (PB), and red-purple (RP), which produces 10 major hues. Each of the 10 major hues is divided into four segments of equal visual steps, which are designated by numerical values applied as prefixes to the symbol for the hue name. For example, between the major hues of 5YR and 5Y are equally spaced steps of 7.5YR, 10YR, and 2.5Y. The standard chart for soil has separate hue cards from 10R through 5Y as indicated in the figure below. Again, the hue card for 10YR is given in the two figures above.

- ***Value*** indicates the degree of lightness or darkness of a color in relation to a neutral gray scale. On a neutral gray (achromatic) scale, value extends from pure black (0/-bottom row of the hue card) to pure white (10/-top row of the hue card) (See the figure above for the card of 10YR hue). The value notation is a measure of the amount of light that reaches the eye under standard lighting conditions. Gray is perceived as about halfway between black and white and has a value notation of 5/. The value is the number recorded after the hue card notation, for example 10YR 5/.

- ***Chroma*** is the relative purity or strength of the spectral color. Chroma indicates the degree of saturation of neutral gray by the spectral color. The scales of chroma for soils extend from /0 for neutral colors (the left-hand column on the hue card) to a chroma of /8 (the right-hand column on the hue card) as the strongest expression of color used for soils. (See the hue card figure above showing horizontal arrangement of increasing chroma from left to right.). The chroma is recorded after the slash, for example 10YR 5/4. This is a full notation of soil color.




A schematic diagram of relationships among the five principal and five intermediate hues of the Munsell Color System and subdivisions within the part used for most soil colors.

**<u>Conditions for measuring color</u>.** The quality and intensity of the light affect the amount and quality of the light reflected from the sample to the eye. The moisture content of the sample and the roughness of its surface affect the light reflected. Color determination may be inaccurate early in the morning or late in the evening. When the sun is low in the sky or the atmosphere is smoky, the light reaching the sample and the light reflected is redder. Colors also appear different in the subdued light of a cloudy day than in bright sunlight. If artificial light is used, as for color determinations in an office, the light source used must be as near the white light of midday as possible. *Roughness* of the reflecting surface of the soil sample affects the amount of reflected light. The most accurate colors are obtained from surfaces that have not been altered from field conditions.

<u>Dominant Color</u>. The dominant color is the color that occupies the greatest volume of the layer. Dominant color (or colors) is always given first among those of a multicolored layer.. For only two colors, the dominant color makes up more than 50 percent of the volume. For three or more colors, the dominant color makes up more of the volume of the layer than any other color, although it may occupy less than 50 percent. In some layers, no single color is dominant and the first color listed is not more prevalent than others.

<u>Mottling</u>. *Mottling* refers to repetitive color changes that cannot be associated with compositional properties of the soil. Redoximorphic features are a type of mottling that is associated with wetness. Mottles are described by quantity, size, contrast, color, and other attributes in that order.

***Quantity*** is indicated by three percentage classes of the observed surface:

| | |
|---|---|
| *few:* | less than 2 percent, |
| *common:* | 2 to 20 percent, and |
| *many:* | more than 20 percent. |

***Size*** refers to dimensions as seen on a plane surface. Three size classes are used:

| | |
|---|---|
| *fine:* | smaller than 5 mm, |
| *medium:* | 5 to 15 mm, and |
| *coarse:* | larger than 15 mm. |

***Contrast*** refers to the degree of visual distinction that is evident between associated colors:

1. *Faint:* Evident only on close examination.
2. *Distinct:* Readily seen but contrast only moderately with the color to which they are compared.
3. *Prominent:* Contrast strongly with the color to which they are compared.

**<u>The meaning, or use, of soil color:</u>**
Most soil colors are derived from colors of minerals, iron oxides, and organic matter that coast surfaces of soil particles

- Organic matter colors: black or brown
- Iron oxide colors: red, yellow, gray

- Interpreting soil colors – help distinguish different horizons in soil profiles
- Provide qualitative information about current **moisture status**
- Provide insight into **drainage status** of soil

  - Color changes take place when various iron-containing minerals undergo oxidation and reduction.
  - Bright (high chroma) colors through the profile indicate well-drained soils through which water easily passes and in which oxygen is plentiful.
  - Low-chroma colors, such as gray, bluish or gray-green (**gleyed colors**) indicate prolonged anaerobic conditions in which the iron oxides are reduced.
  - The presence of gley, alone, or mixed in a mottle pattern with brighter colors is used in delineating wetlands, because it is indicative of waterlogged conditions during at least a major part of the plant growing season.

o **Examples of Soil Colors**:

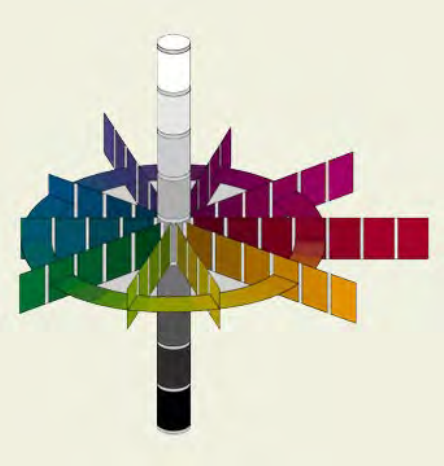
**10YR 6/4 Light Yellowish Brown**

**2.5YR 4/8 Red**

**2.5Y 4/1 Dark Gray**

**10YR 7/1 Light Gray, 5YR 5/8 Yellowish Red, 10YR 6/4 Light Yellowish Brown**

## The Color of Soil



The first impression we have when looking at bare earth or soil is of color. Bright colors especially, catch our eye. Geographers are familiar with Red Desert soils in California, Arizona, and Nevada (Arizona State Soil); and Gray Desert soils in Idaho, Utah, and Nevada (Nevada State Soil). We have the White Sands in New Mexico, Green Sands along the Atlantic Coast, and Redbeds in Texas and Oklahoma (Oklahoma State Soil). The Red River between Oklahoma and Texas carries red sediment downstream, particularly in times of flood. The Yellow River (Hwang Ho) in China carries yellow sediment. Surface soils in the Great Plains and Corn Belt are darkened and enriched by organic matter.

Earth materials found in such locations as those mentioned above were used as coloring agents early in the development of most human cultures. As earth material was fashioned into utilitarian vessels, artistic colors inevitably were incorporated into them. Indigenous North American cultures used contrasting earth colors as body paints, and modern American culture uses colored earth in cosmetics and ceramics and as pigments for paints.

### Munsell Color System

Red, brown, yellow, yellowish-red, grayish-brown, and pale red are all good descriptive colors of soil, but not very exact. Just as paint stores have pages of color chips, soil scientists use a book of color chips that follow the Munsell System of Color Notation (www.munsell.com). The Munsell System allows for direct comparison of soils anywhere in the world. The system has three components: hue (a specific color), value (lightness and darkness), and chroma (color intensity) that are arranged in books of color chips. Soil is held next to the chips to find a visual match and assigned the corresponding Munsell notation. For example, a brown soil may be noted as: hue value/chroma (10YR 5/3). With a soil color book with Munsell notations, a science student or teacher can visually connect soil colors with natural environments of the area, and students can learn to read and record the color, scientifically. Soil color by Munsell notation is one of many standard methods used to describe soils for soil survey. Munsell color notations can be used to define an archeological site or to make comparisons in a criminal investigation. Even carpet manufacturers use Munsell soil colors to match carpet colors to local soils so that the carpet will not show the dirt (soil) tracked into the house.

## Soil Composition and Color

Soil color and other properties including texture, structure, and consistence are used to distinguish and identify soil horizons (layers) and to group soils according to the soil classification system called *Soil Taxonomy*. Color development and distribution of color within a soil profile are part of weathering. As rocks containing iron or manganese weather, the elements oxidize. Iron forms small crystals with a yellow or red color, organic matter decomposes into black humus, and manganese forms black mineral deposits. These pigments paint the soil (Michigan State Soil). Color is also affected by the environment: aerobic environments produce sweeping vistas of uniform or subtly changing color, and anaerobic (lacking oxygen), wet environments disrupt color flow with complex, often intriguing patterns and points of accent. With depth below the soil surface, colors usually become lighter, yellower, or redder.

## Interpreting Soil Color

Color can be used as a clue to mineral content of a soil. Iron minerals, by far, provide the most and the greatest variety of pigments in earth and soil (see the following table).

## Properties of Minerals

| Mineral | Formula | Size | Munsell | Color |
|---|---|---|---|---|
| goethite | FeOOH | (1-2 µm) | 10YR 8/6 | yellow |
| goethite | FeOOH | (~0.2 µm) | 7.5YR 5/6 | strong brown |
| hematite | $Fe_2O_3$ | (~0.4 µm) | 5R 3/6 | Red |
| hematite | $Fe_2O_3$ | (~0.1 µm) | 10R 4/8 | Red |
| lepidocrocite | FeOOH | (~0.5 µm) | 5YR 6/8 | reddish-yellow |
| lepidocrocite | FeOOH | (~0.1 µm) | 2.5YR 4/6 | Red |
| ferrihydrite | $Fe(OH)_3$ | | 2.5YR 3/6 | dark red |
| glauconite | $K(Si_xAl_{4-x})(Al,Fe,Mg)O_{10}(OH)_2$ | | 5Y 5/1 | dark gray |
| iron sulfide | FeS | | 10YR 2/1 | black |
| pyrite | $FeS_2$ | | 10YR 2/1 | black (metallic) |

| | | | | |
|---|---|---|---|---|
| jarosite | $K Fe_3 (OH)_6 (SO_4)_2$ | | 5Y 6/4 | pale yellow |
| todorokite | $MnO_4$ | | 10YR 2/1 | black |
| humus | | | 10YR 2/1 | black |
| calcite | $CaCO_3$ | | 10YR 8/2 | white |
| dolomite | $CaMg (CO_3)_2$ | | 10YR 8/2 | white |
| gypsum | $CaSO_{4\times} 2H_2O$ | | 10YR 8/3 | very pale brown |
| quartz | $SiO_2$ | | 10YR 6/1 | light gray |

Relatively large crystals of goethite give the ubiquitous yellow pigment of aerobic soils. Smaller goethite crystals produce shades of brown. Hematite (Greek for blood-like) adds rich red tints. Large hematite crystals give a purplish-red color to geologic sediments that, in a soil, may be inherited from the geologic parent material. In general, goethite soil colors occur more frequently in temperate climates, and hematite colors are more prevalent in hot deserts and tropical climates.

Color - or lack of color - can also tell us something about the environment. Anaerobic environments occur when a soil has a high water table or water settles above an impermeable layer. In many soils, the water table rises in the rainy season. When standing water covers soil, any oxygen in the water is used rapidly, and then the aerobic bacteria go dormant. Anaerobic bacteria use ferric iron ($Fe^{3+}$) in goethite and hematite as an electron acceptor in their metabolism. In the process, iron is reduced to colorless, water-soluble ferrous iron ($Fe^{2+}$), which is returned to the soil. Other anaerobic bacteria use $Mn^{4+}$ as an electron acceptor, which is reduced to colorless, soluble $Mn^{2+}$. The loss of pigment leaves gray colors of the underlying mineral. If water stays high for long periods, the entire zone turns gray.

When the water table edges down in the dry season, oxygen reenters. Soluble iron oxidizes into characteristic orange colored mottles of lepidocrocite (same formula as goethite but different crystal structure) on cracks in the soil. If the soil aerates rapidly, bright red mottles of ferrihydrite form in pores and on cracks. Usually ferrihydrite is not stable and, in time, alters to lepidocrocite.

Along seacoasts, tide waters saturate soils twice daily, bringing soluble sulfate anions. Anaerobic bacteria use the sulfate as an electron acceptor and release sulfide ($S^{2-}$) which combines with ferrous iron to precipitate black iron sulfide. A little hydrochloric acid (HCl) dropped on this black pigment quickly produces a rotten egg odor of hydrogen sulfide ($H_2S$) gas. Soils that release $H_2S$ gas are called sulfidic soils. With time, iron sulfide alters to pyrite ($FeS_2$) and imparts a metallic bluish color. If sulfidic soils are drained and aerated, they quickly become very acid (pH 2.5 to

3.5), and a distinctive pale yellow pigment of jarosite forms. This is the mark of an acid sulfate soil that is quite corrosive and grows few plants.

Galuconitic green sands form in shallow ocean water near a coast. They become part of soils that form after sea level drops. White colors of uncoated calcite, dolomite, and gypsum are common in geologic materials and soils in arid climates. A little carbonate dissolves in water, moves downward, and precipitates in soft white bodies or harder nodules. It also accumulates in root pores as lacy, dendritic (tree-branch) patterns.

## Influence of Organic Matter on Soil Color

Soil has living organisms and dead organic matter, which decomposes into black humus. In grassland (prairie) soils the dark color permeates through the surface layers bringing with it nutrients and high fertility (Kansas State Soil). Deeper in the soil, the organic pigment coats surfaces of soil, making them darker than the color inside. Humus color decreases with depth and iron pigments become more apparent. In forested areas, organic matter (leaves, needles, pine cones, dead animals) accumulates on top of the soil. Water-soluble carbon moves down through the soil and scavenges bits of humus and iron that accumulate below in black, humic bands over reddish iron bands. Often, a white layer, mostly quartz occurs between organic matter on the surface where pigments were removed (Wisconsin State Soil).

Organic matter plays an indirect, but crucial role in the removal of iron and manganese pigments in wet soils. All bacteria, including those that reduce iron and manganese, must have a food source. Therefore, anaerobic bacteria thrive in concentrations of organic matter, particularly in dead roots. Here, concentrations of gray mottles develop.

Soil color is a study of various chemical processes acting on soil. These processes include the weathering of geologic material, the chemistry of oxidation-reduction actions upon the various minerals of soil, especially iron and manganese, and the biochemistry of the decomposition of organic matter. Other aspects of Earth science such as climate, physical geography, and geology all influence the rates and conditions under which these chemical reactions occur.

Soil adds beauty to our landscapes. These colors blend with vegetation, sky, and water. For art students and others who may be interested in creating a natural look to their artwork, try to incorporate finely ground colored soils as pigments into your work.

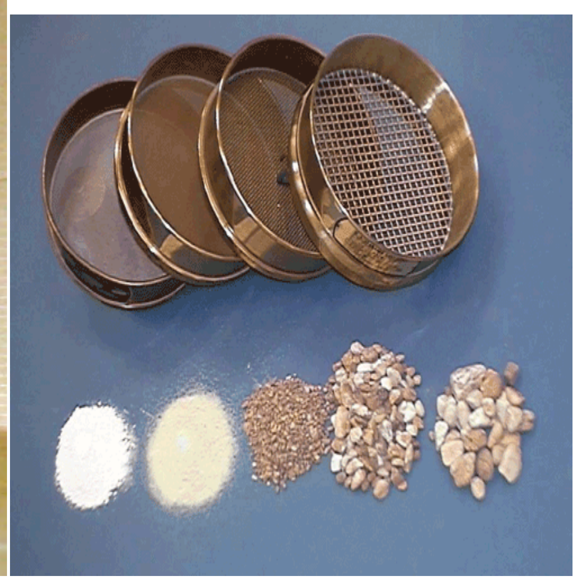
## B. Soil Texture

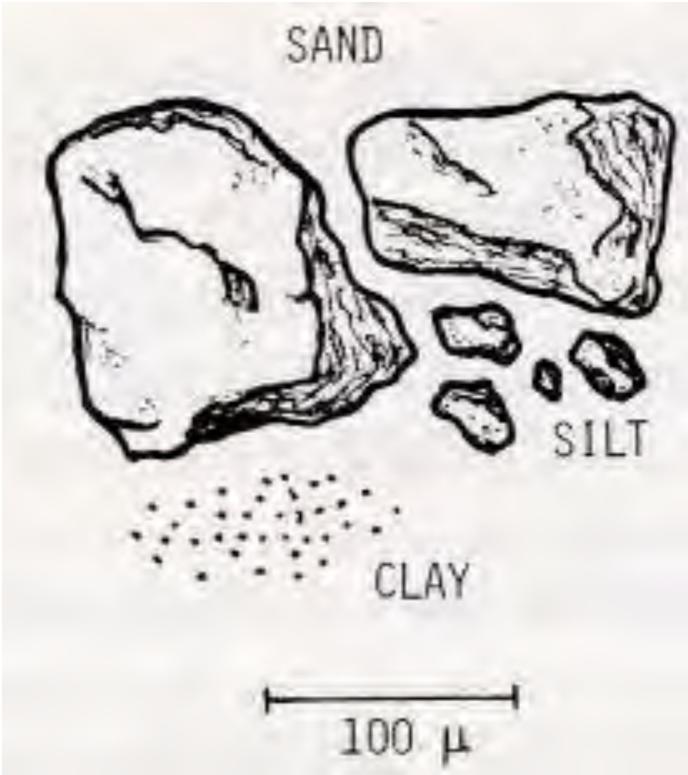
### B.1 Particle Size Distribution

Definition. Soil is made up of about 50% mineral particles, 25% water and 25% air. Particle size is the diameter of a mineral particle as measured by sedimentation or sieving. The figures below show sedimentation cylinders and sieves. Particle sizes are expressed as classes with specific, diameter class ranges. The broad classes are clay, silt, and sand, ranging from the smaller to the larger of the less than 2 mm mineral soil fraction (see particle size figure below). Particle-size distribution of the fine earth or less than 2- mm diameter fraction is determined in the field mainly by feel. Texture is the relative proportion of these mineral particles (sand, silt, clay).

Significance. The physical behavior of a soil is influenced by the size and percentage composition of the size classes. Particle size is important for most soil use and management classifications, for determination of soil hydrologic properties, and for soil classification.








- Soil is made up of about 50% mineral particles, 25% water and 25% air
- The mineral particles are divided into sand, silt and clay
- Texture is the relative proportion of these mineral particles (sand, silt, clay)
- The size distribution of soil particles

  sand (large particles) 0.05 mm to 2.0mm
  silt (medium-sized particles) 0.002 mm to <0.05 mm
  clay (smallest-sized particles) <.002 mm

**Soil Separates**

Classes. The United States Department of Agriculture uses the following size separates for the <2 mm mineral material:

| | |
|---|---|
| Clay, total | <0.002 mm |
| Silt, total | 0.002 - 0.05 mm |
| Silt, fine | 0.002 - 0.02 mm |
| Silt, coarse | 0.02 - 0.05 mm |
| Sand total | 0.05 - 2.00 mm |
| Very fine sand | 0.05 - 0.10 mm |
| Fine sand | 0.10 - 0.25 mm |
| Medium sand | 0.25 - 0.50 mm |
| Coarse sand | 0.50 - 1.00 mm |
| Very coarse sand | 1.00 - 2.00 mm |

## Soil Texture

Soil texture refers to the weight proportion of the separates for particles less than 2 mm as determined from a laboratory particle-size distribution. Sand particles feel gritty and can be seen individually with the naked eye. Silt particles cannot be seen individually without magnification; they have a smooth feel to the fingers when dry or wet. In some places, clay soils are sticky; in others they are not. Soils dominated by montmorillonite clays, for example, feel different from soils that contain similar amounts of micaceous or kaolintic clay.

Clay percentage. Total clay percentage is the weight percentage of the mineral particles less than 0.002 mm in equivalent diameter in the less than 2 mm soil fraction. Most of the material is in one of three groups of clay minerals: kaolinite, smectite, and mica.

Physical and chemical activities of a soil are related to the kind and amount of clay minerals. Clay particles may have thousands of times more surface area per gram than silt particles and nearly a million times more surface area than very coarse sand particles. Thus, clay particles are the most chemically and physically active part of mineral soil. Clay mineralogy and clay percentage have a strong influence on engineering properties and the behavior of soil material when it is used as construction or foundation material. They influence compressibility, bearing strength, and permeability.

The kind and amount of clay influence plant growth indirectly by affecting available water capacity, water intake rate, aeration, cation exchange capacity, permeability, or saturated hydraulic conductivity, erodibility, and workability. Up to a certain point, an increase in the amount of clay in the subsoil is desirable. Clay can increase the amount of water and nutrients stored in that zone. By slightly slowing the rate of water movement, it can reduce the rate of nutrient loss through leaching. If the amount of clay is great, it can impede water and air movement, restrict root penetration, increase runoff and, on sloping land, result in increased erosion.

Clay particles are removed by percolating water from surface and subsurface horizons and deposited in the subsoil horizons. The amount of clay accumulation and its location in the profile provide clues for the soil scientist about soil genesis.

Silt Percentage. Silt percentage is the weight percentage of the mineral particles greater than or equal to 0.002 mm but less than 0.05 mm in the less than 2 mm soil fraction. The silt separate is dominated by primary minerals, especially quartz, and therefore has a low chemical activity.

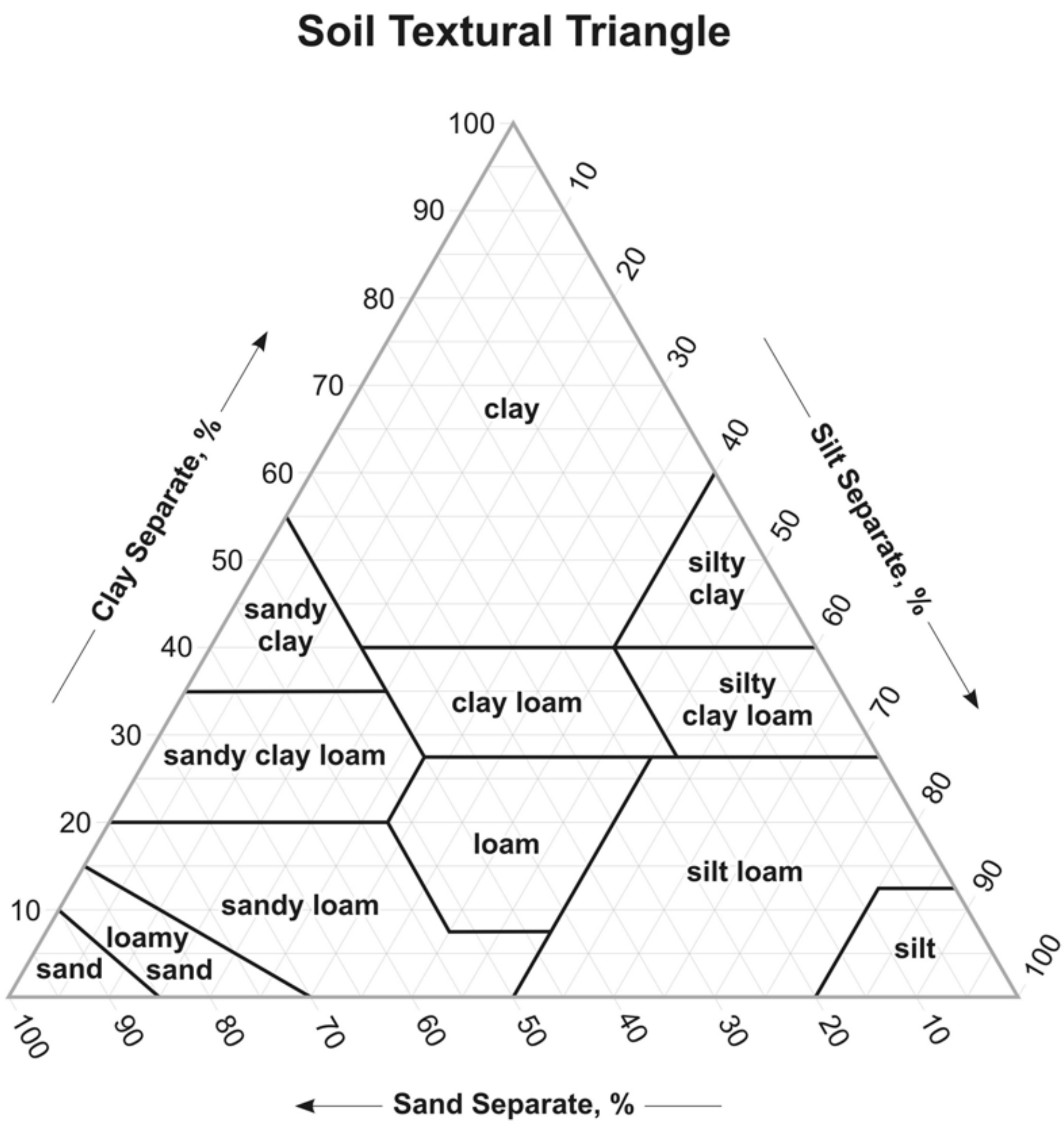
The silt separate possesses some plasticity, cohesiveness, and absorption, but to a much lesser degree than the clay separate. Silt particles act to slow water and air movement through the soil by filling voids between sand grains. A very high content of silt in a soil may be physically undesirable for some uses unless supplemented by adequate amounts of sand, clay, and organic matter. Soils high in silt are the most easily eroded and attention must be given to proper land use and erosion control practices.

Sand Percentage. Sand percentage is the weight percentage of the mineral particles less than 2 mm and greater than or equal to 0.05 mm in equivalent diameter in the less than 2 mm soil fraction. The sand separates recognized are very coarse, coarse, medium, fine, very fine, and total. Respective size limits are shown in the paragraph above. Much of the sand fraction is composed of fragments of rocks and primary minerals, especially quartz. Therefore, the sand fraction is quite chemically inactive.

Physical properties of the soil are influenced by the amounts of total sand and of the various sand fractions present in the soil. Sand particles, because of their size, have a direct impact on the porosity of the soil. This influences other properties, such as permeability, available water capacity, water intake rates, aeration, and compressibility related to plant growth and engineering uses.

**B.2 Texture Classes**

The texture classes are sand, loamy sands, sandy loams, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay..The texture triangle (see figure below) is used to resolve problems related to word definitions, which are somewhat complicated.



**Groupings of soil texture classes.—**Often it is convenient to speak generally of broad groups or classes of texture. An outline of soil texture groups follows..

| *General terms* | *Texture classes* |
|---|---|
| **Sandy soil materials** | |
| Coarse-textured | Sands (coarse sand, sand, fine sand, very fine sand) Loamy sands (loamy coarse sand, loamy sand, loamy fine sand, loamy very fine sand) |
| **Loamy soil materials** | |
| Moderately coarse-textured | Coarse sandy loam, sandy loam, fine sandy loam |
| Medium-textured | Very fine sandy loam, loam, silt loam, silt |
| Moderately fine-textured | Clay loam, sandy clay loam, silty clay loam |
| **Clayey soils** | |
| Fine-textured | Sandy clay, silty clay, clay |

**General Textural Class Determination by Feel**

- Sand particles: feel gritty when rubbed; hold little water or nutrients; sandy soils prone to drought. The degree of grittiness in a wet soil sample, when worked between the thumb and forefinger, gives an estimate of the sand content. The size of sand grains may be observed with the naked eye or with the aid of a hand lens.

- Silt particles: invisible to naked eye; feel smooth, silky, and flour-like when rubbed; hold a significant amount of plant nutrients. The silt content may be estimated in the field using the ribbon test as described for clay. The content of silt is usually estimated by first estimating the clay and sand portions and then subtracting that number from 100 percent. Silt tends to give the soil a smooth feel.

- Clay particles: invisible to naked eye; huge capacity to absorb water and hold plant nutrients; feel very smooth and slick when rubbed; sticky when wet.

| Texture | Feels Gritty | Sticky | Forms Ball | Forms Ribbon | Stains Fingers |
|---|---|---|---|---|---|
| **Sandy** | Very | No | No | No | No |
| **Loamy** | Moderately | No | Yes | Short | Yes |
| **Clayey** | No | Very | Yes | Long | Yes |

- It is more convenient, quick, and practical to estimate the textural names of soils by rubbing between two fingers. Moisten the soil to a consistency of workable putty. Make a ball of about 1/2 –inch diameter. Hold the ball between the thumb and the forefinger. Press your thumb forward forming the soil into a ribbon. With the fine textures soils like clay or silty clay the ribbon remains long and flexible. Soils in this group are very sticky and plastic when wet. If a ribbon is not formed, the sample is probably a silt loam, sandy loam or loam, which would place it in the medium textural division. If the soil feels smooth and talc-like, with no grittiness, silt predominates and the soil is also termed medium textured. If the soil feels gritty and lacks smoothness, this would indicate that most likely, the sand particle predominates. The soil is then considered a coarse texture.

- Sandy soils tend to be characterized by low strength and a greater susceptibility to wind erosion and less water available to plants than soils of other textures. In addition, trenches and banks in sandy soil are highly susceptible to caving, which may pose a safety hazard. Water may pipe through terraces and other water impoundments.

- Clayey soils generally have more available water than sandy soils. Clayey soils have the greatest capacity to shrink and swell. They retain large quantities of water, which affect tillage practices and can contribute to soil creep or landslides in sloping areas. Clays also have strong adhesive properties that bond particles together. Generally, the cation-exchange capacity increases with increases in content of clay and organic matter. Soils that have large amounts of clay fix more phosphorus than soils that have less clay

- Silty soils have a higher available water capacity than sandy soils. In the absence of clay particles, silt soils have lower adhesive properties. Piping through terraces, levees, and pond embankments can be a problem. Trenches may cave, particularly in saturated soils.

**B.3 Questions on Soil Texture**

<u>What are the origins of soil mineral particles?</u> Weathering of sedimentary, igneous, and metamorphic rocks.

<u>What is the weathering process?</u> The physical and chemical breakdown and changes in rocks and sediments at or near Earth's surface produced by biological, chemical, and physical agents

<u>How do particle sizes help us to understand soil formation processes?</u> This can be seen by a simple demonstration where soil is vigorously shaken in a container with water and then observing the settling or sedimentation of the soil particles (see "Dirt Shake" figure below.) The particles settle according to sizes, with the larger sand particles settling first, followed by silt, then clay. The clay takes much longer to settle than the others. In alluvial flood plains, such as the Mississippi River Alluvial Floodplain, or Delta, sandy soil materials, or course-textured soils are situated close to streams as these particle sizes settled first from flood waters. Furthest from the stream channels are the clayey soils, which formed in what was called backwater swamps, i.e., the last of the floodwater reaching more level terrain and providing adequate settling time for the clay-sized particles (see floodplain figure below).

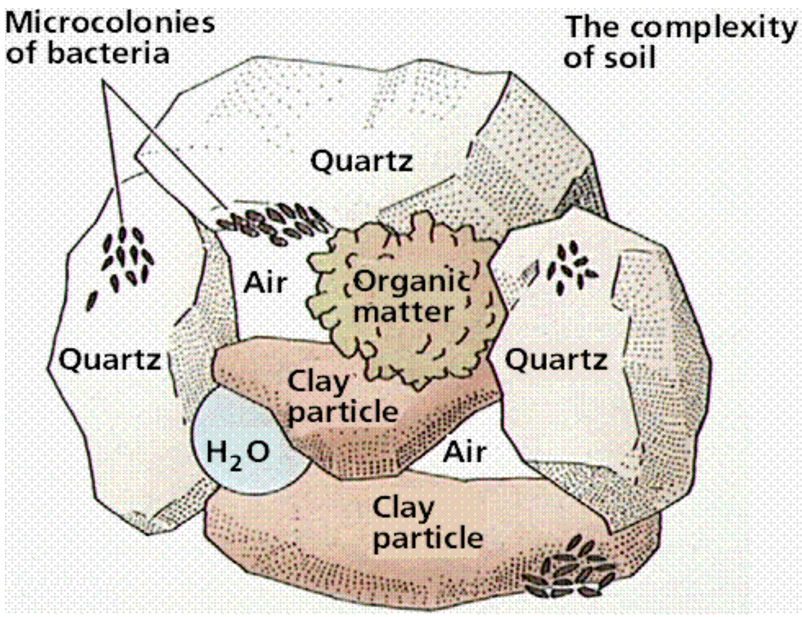
What is the role of texture in the filtering capacity of soils? A simple experiment gives a vivid illustration of the influence of texture on filtration of soil water. A series of plastic containers are arranged such that soil water added to the top container passes through the soil and onto the soil in the container below and so on until it reaches a reservoir at the bottom of the chain. Food coloring is added to the water and the results observed as in the photo below. Finer textured soils filter the water best because of their high content of reactive mineral surfaces and large surface areas. Sandy soils have far less ability to filter water. Which soil below has a higher percentage of smaller particle-sizes? What do the results shown below mean with respect to land use?

## C. Soil Structure

- Soil structure is defined by the way individual particles of sand, silt, and clay are assembled, or arranged. Single particles when assembled appear as larger particles. These are called aggregates, or peds. A soil structure refers to the aggregation of individual soil particles into large units, oriented in a manner, which gives a geometrical shape or form.

- Soil structure affects water and air movement through soil, greatly influencing soils' ability to sustain life and perform other vital functions.

**Soil Aggregate**




- Clay particles carry a negative charge on their surface that can cause them to repel each other, but that attracts and adsorbs cations present in the soil.

- Stacks of clay particles can form when their negative surface charge is neutralized by tightly adsorbed polyvalent cations, such as $Ca^{2+}$ and $Al^{3+}$.

- Further, $Ca^{2+}$, $Fe^{2+}$ and $Al^{3+}$ flocculate (clump together) stacks of clay particles, and with humus (negatively charged, highly decomposed, stable organic matter), bind to form small, stable soil aggregates.

- While chemical and physical factors play a prominent role in small aggregate formation in clay soils, biological processes are important for development of large aggregates and macropores, and they are the primary factor for aggregation of sandy soils.

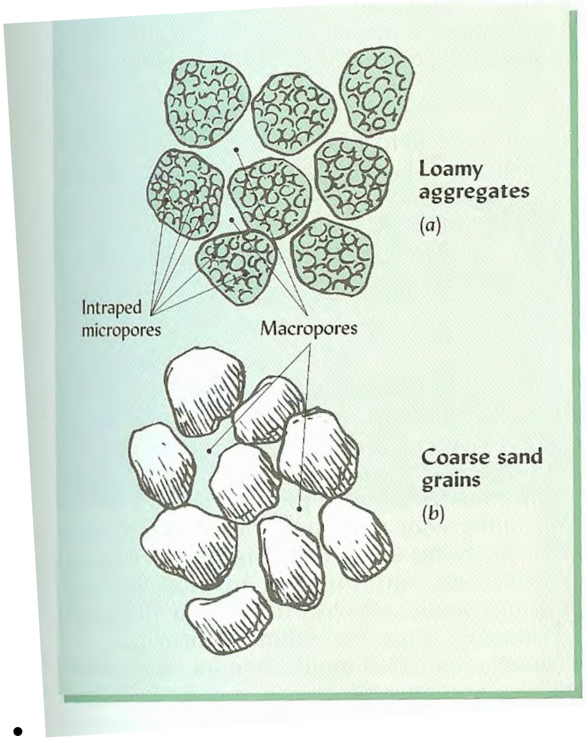



FIGURE 4.16 A schematic comparison of sandy and clayey soils showing the relative amounts of large (macro-) pores and small (micro-) pores in each. There is less total pore space in the sandy soils than in the clayey one because the clayey soil contains a large number of fine pores within each aggregate (*a*), but the sand particles (*b*), while similar in size to the clayey aggregates, are solid and contain no pore spaces within them. This is the reason why, among surface soils, those with coarse texture are usually more dense than those with finer textures.

(from: Brady and Weil Nature and Property of Soils,12th ed. 1999)

- Important biological processes include: earthworms burrowing in soil and ingesting soil particles to form casts, development of sticky networks of roots and fungal hyphae, and production of organic glues by fungi and bacteria.

- Plant roots also contribute to aggregation and development of macropores as they push through the soil while they are growing or by leaving channels when they die.

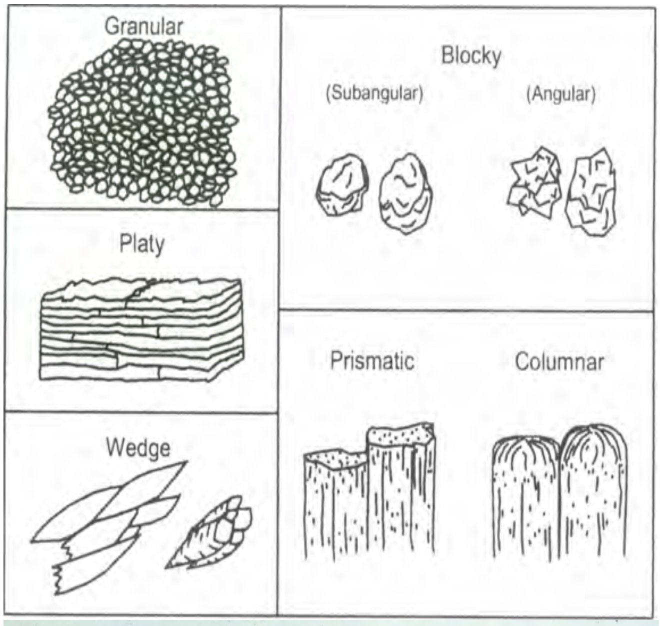
- Organic matter is the major contributing factor for aggregate formation that can be directly affected by human management. It provides energy for microbial processes that release organic products.

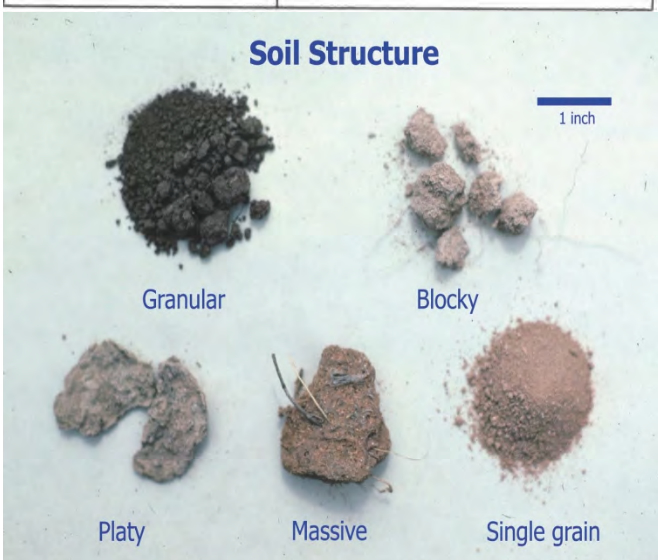
- The organic products chemically interact with soil particles and iron and aluminum oxides to bind soil particles together into aggregates.

- Activities such as timber harvesting, grazing, tillage, construction, drainage, fertilizing and liming impact the soils mainly through their effect on soil structure, especially in the surface horizons.

## Types of Soil Structure

**Shape** – several basic shapes of structural units are recognized in soils (See figure below).



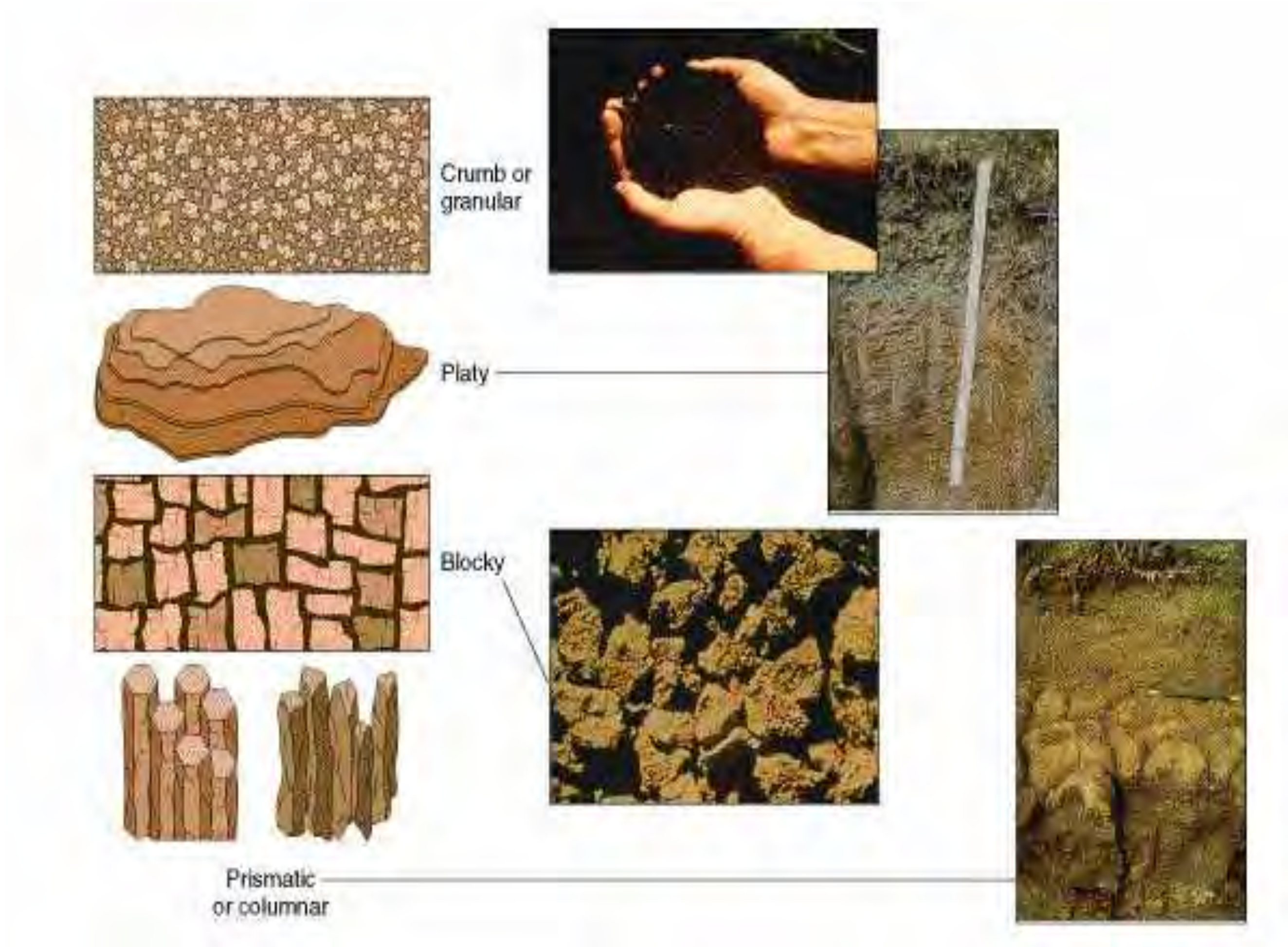

**Granular**: The units are approximately spherical or polyhedral and are bounded by curved or very irregular faces that are not casts of adjoining peds.

**Platy**: The units are flat and platelike. They are generally oriented horizontally. Platy structure is illustrated below. A special form, lenticular platy structure, is recognized for plates that are thickest in the middle and thin toward the edges.

**Prismatic**: The individual units are bounded by flat to rounded vertical faces. Units are distinctly longer vertically, and the faces are typically casts or molds of adjoining units. Vertices are angular or subrounded; the tops of the prisms are somewhat indistinct and normally flat.

**Columnar**: The units are similar to prisms and are bounded by flat or slightly rounded vertical faces. The tops of columns, in contrast to those of prisms, are very distinct and normally rounded.

**Blocky**: The units are blocklike or polyhedral. They are bounded by flat or slightly rounded surfaces that are casts of the faces of surrounding peds. Typically, blocky structural units are nearly equidimensional but grade to prisms and to plates. The structure is described as angular blocky if the faces intersect at relatively sharp angles; as subangular blocky if the faces are a mixture of rounded and plane faces and the corners are mostly rounded.




- Common soil structures in Mississippi:
  A horizon: granular structure
  B horizon: blocky structure

**C.1. Soil Bulk Density**

Definition. Bulk density is the oven-dried weight of the less than 2 mm soil material per unit volume of soil.

Significance. Soil density is a measure of the heaviness of soil. As a general rule of thumb, the harder the soil, the denser the soil. Bulk density influences plant growth and engineering applications.

- The structure of soil molecules also affects bulk density measurements.
- Average soil bulk density for standard, healthy mineral solids runs between **1.0** and **2.0** grams per square centimeter.
- Within a soil texture class, bulk density is an indicator of how well plant roots are able to extend into the soil. Root-restriction initiation and root-limiting bulk densities are shown below for various family particle size classes.

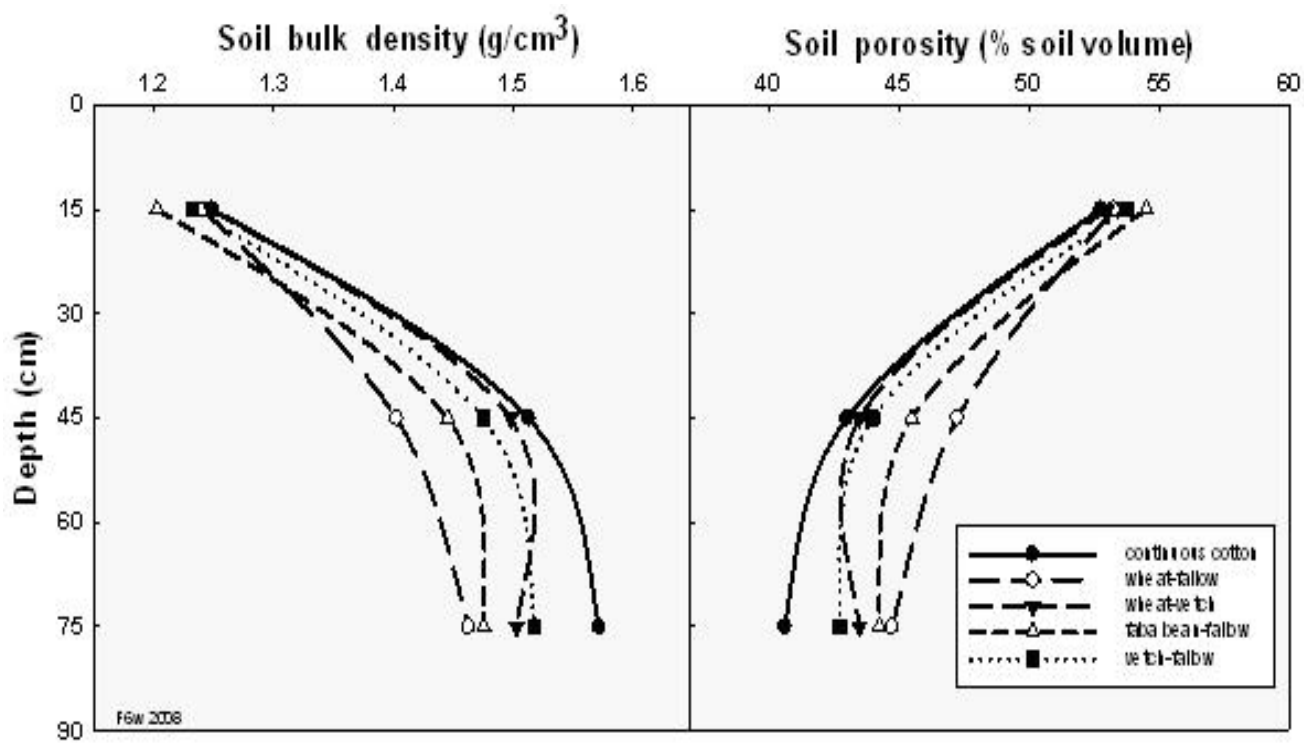
| **Texture Classes** | **Bulk density (g cm$^{-3}$)** | |
|---|---|---|
| | **Restriction-initiation** | **Root-limiting** |
| **Sandy** | 1.69 | >1.85 |
| **Loamy** | | |
| coarse-loamy | 1.63 | >1.80 |
| fine-loamy | 1.60 | >1.78 |
| coarse-silty | 1.60 | >1.79 |
| fine-silty | 1.54 | >1.65 |
| **Clayey** | | |
| 35-45% clay | 1.49 | >1.58 |
| >45% clay | 1.39 | >1.47 |

  - Measuring soil density helps gardeners and landscapers determine which plants are suitable for growth in a certain area or whether soil requires replacing and amending in order for cultivation to successfully occur.
  - High bulk densities may occur as a natural feature in the soil, such as a fragipan or some type of cemented horizon. These horizons are so dense that it requires great effort to excavate soil with a shovel or backhoe.
  - Bulk density is susceptible to change stemming from human activity. Many activities such as tillage, timber harvesting and recreation have the potential to compact the soil to such an extent those plants cannot grow. Alternatively, adding organic residue to the soil can lower bulk density by improving soil structure and increasing pore space.
  - Soil density relates to a number of other important considerations for plant cultivation, including porosity and water availability.

**C.2. Porosity.** Porosity is the volume percentage of the total soil bulk not occupied by solid particles. Bulk density is used to calculate porosity. The higher the bulk density value, the lower the amount of porosity. Therefore, bulk density is an indicator of aeration and compaction.

- Soil structure affects the amount of pore space as well as the size and orientation of pores.

- Platy structures are densely packed vertically so pores have smaller diameters. Pores are very tortuous, winding back and forth along relatively long horizontal and short vertical distances. It can take a long time for air and water in the soil to move upward or downward due to the nature of pores in platy structured soils.
- Soils with granular and subangular blocky structure have many large pores between peds or aggregates and it is easy for air and water to move from one pore to the next; movement is rapid and in a fairly direct line.

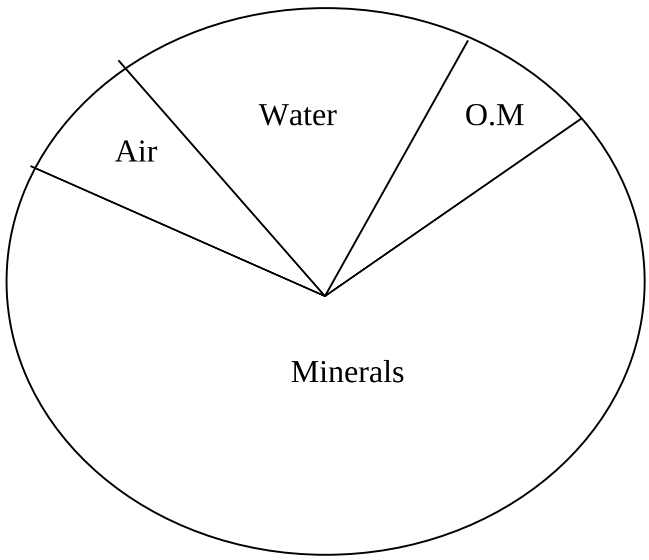



- Soils with high porosity allow air to reach plant roots and retain water. Though soils with high porosity levels benefit plants, soils with too high porosity levels may drown plants by retaining too much water and in some cases cause drought conditions by allowing water to move excessively through the soil.

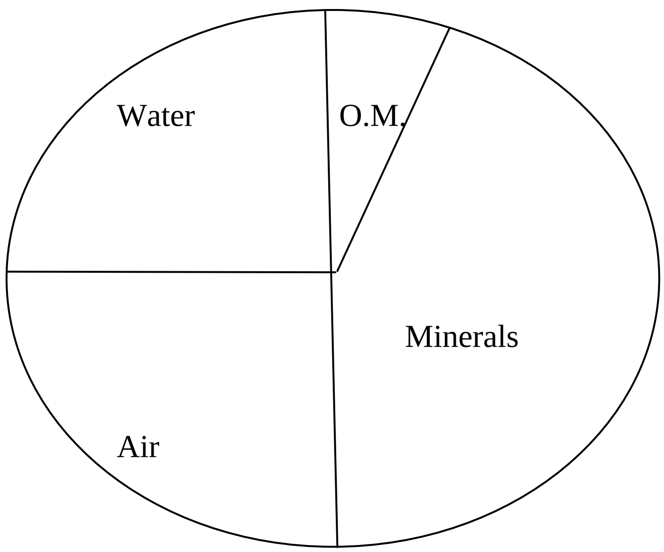
- Finer particles like silt and clay typically have less pore space than sand particles resulting in lower bulk densities. Soils dominated by sand typically have higher densities because of the larger amounts of pore space.

- **<u>Soil compaction</u>** occurs when soils get compressed. Compacted soils contain a much higher volume of soil particles (and less pore space) than do non-compacted soils, and thus have much higher bulk density and much lower porosity measurements.

**A Compacted Soil**




**An Ideal Soil**



**Plant Growth Significance.** According to many researchers, soil compaction constitutes the single most harmful condition for plant specimens.

- The high density of compacted soil prevents plant roots from growing by strangling and starving the plant roots. Plants have great difficulty in rooting soil with low porosity and compacted soil exhibits low water retention, making it difficult for plants to obtain moisture and nutrients through the soil.

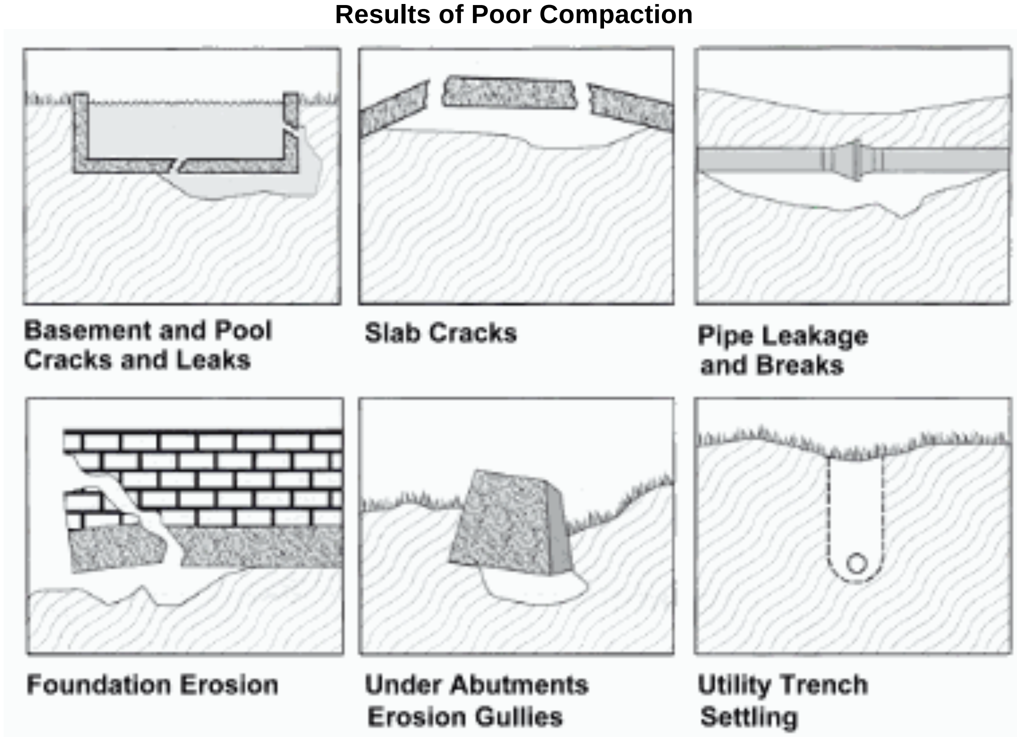
- Soil in urban areas generally exhibits greater bulk density and soil compaction than soils in natural, rural or suburban areas. The heavy human and vehicular traffic of urban areas, along with lack of space and high density of buildings, leads to highly compressed soil.

**Engineering significance** Soil strength increases with higher bulk densities and decreases with higher moisture content. Compaction of the soil usually increases bulk density and soil strength.

- Soil compaction and soil strength are benefits for road and building construction, because we want the soil to be stable and packed in order to support a large amount of weight.

**Examples of use failures as it relates to soil compaction**

**Results of Poor Compaction**



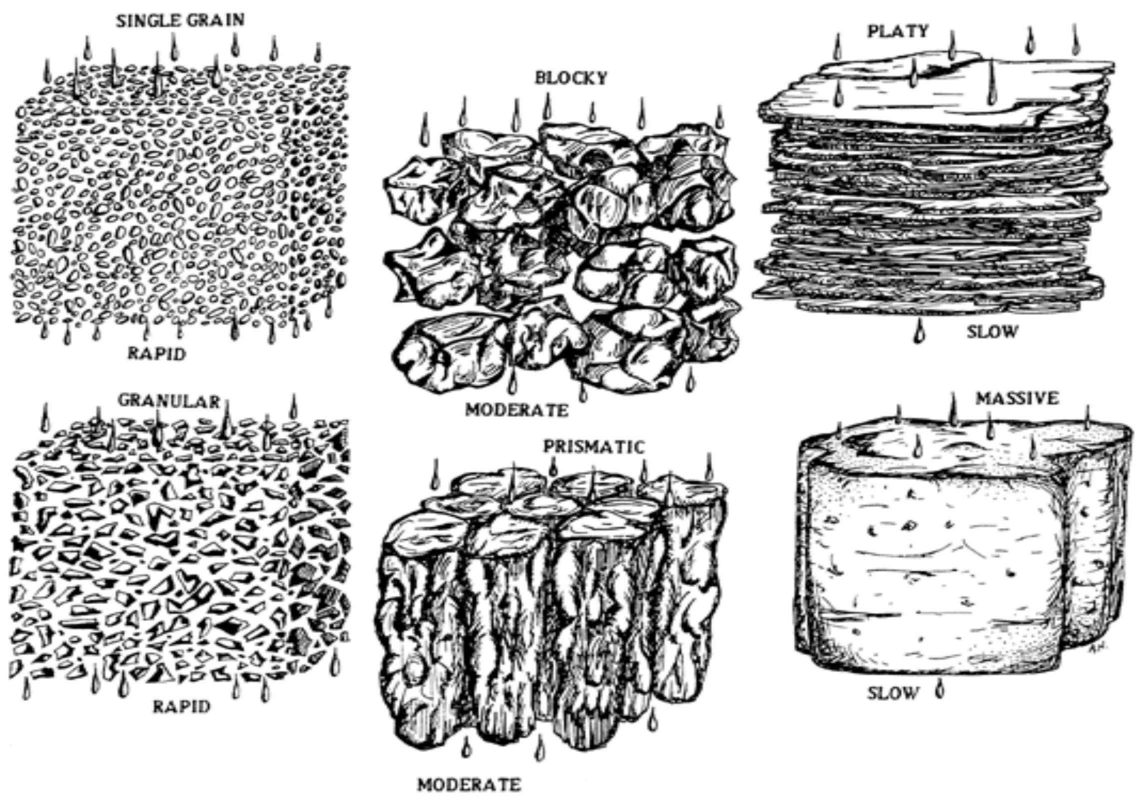
## C.3. Soil Permeability

Definition. Permeability is the rate at which air and water move through the soil pore spaces

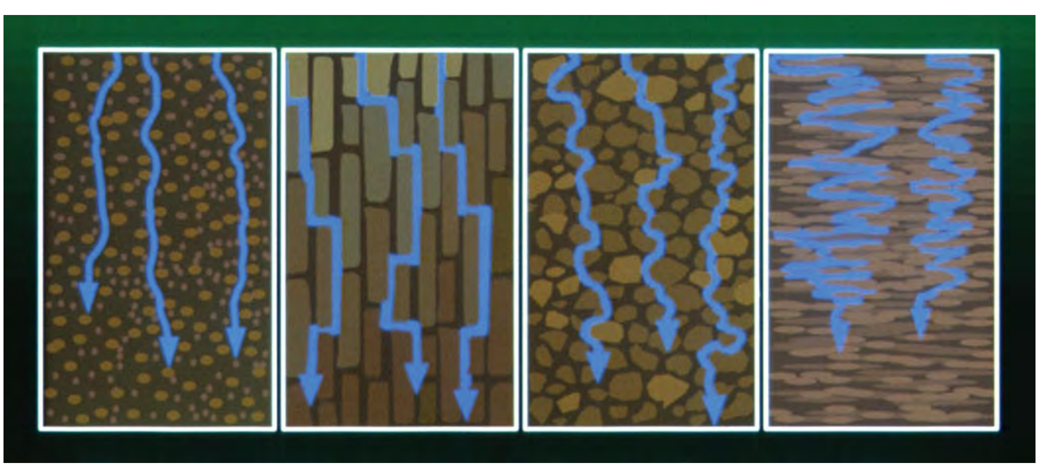
- Pore spaces:
    - Macro (large) pores quickly drain excess water that is replaced by air
    - Micro (small) pores hold plant available water

Significance. It is determined by soil texture, dense or restrictive layers, and soil structure

- Rapid permeability:  coarse textures (high sand content), stable structure with large pores
- Very slow permeability:  fine texures (high clay content), restrictive layers, absence of large pores, grey colors, mottling
- Soil structure effects water movement through soil (See figure below)




**Water movement through granular, prismatic, subangular blocky, and platy soils, respectively.**

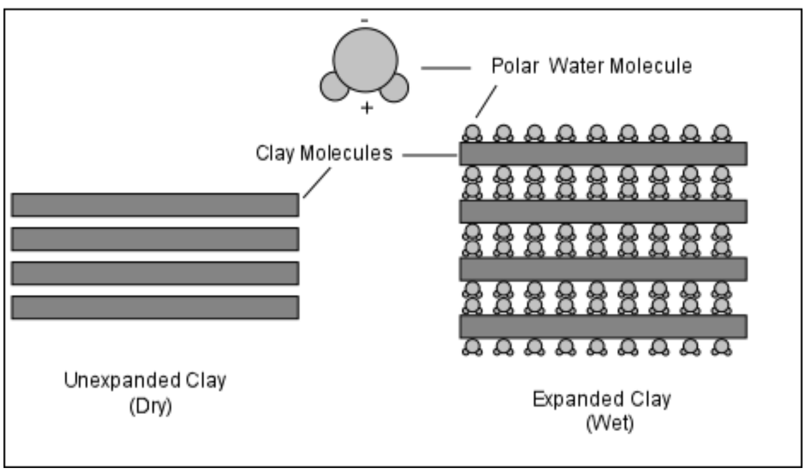


### C.3.1. Cracks

Soil cracking is caused by the change in volume with changes in moisture content, that is, the extent to which the soil shrinks as it dries out. The same soil swells when it gets wet and the cracks close.

- The extent of shrinking and swelling is influenced by the amount and kind of clay in the soil. Shrinking and swelling of soils causes much damage to building foundations, roads and other structures. A high shrink/swell potential indicates a hazard to maintenance of structures built in, on, or with material having this rating.

- The kind of clay mineral that leads to shrinking and swelling is called smectite. There are several kinds of smectite clay minerals; the most common one in Mississippi soils is called montmorillonite. As the soil wets, water moves between the clay layer and it expands. When it dries the layers collapse and the volume is reduced, leading to shrinkage of the soil and cracking. The amount of smectite determines the degree of shrinking and swelling. (See figures below.)




## C.3.2. Surface Crusts

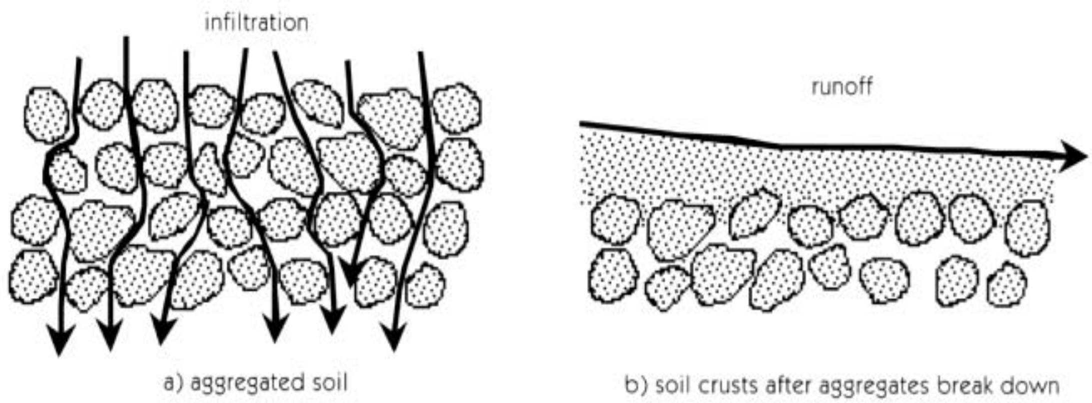
- Soil crusts are relatively thin, somewhat continuous layers of the soil surface that often restrict water movement, air entry, and seedling emergence from the soil. They generally are less than 2 inches thick and are massive.

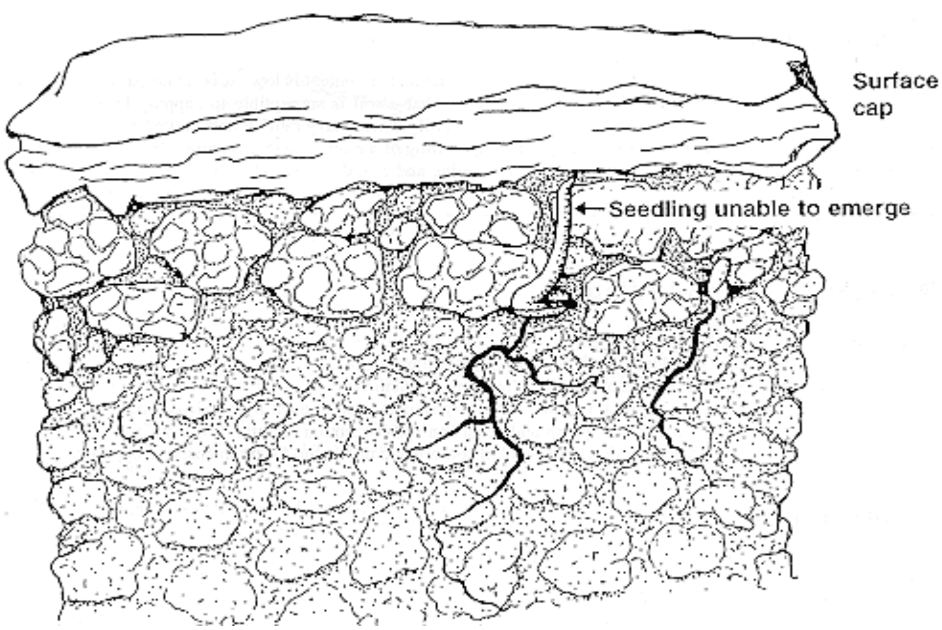
- Crusts are created by the breakdown of structural units by or raindrops.

- If the soil is not protected by a cover of growing plants, crop residue or other material, and if soil aggregates are weak, the energy can cause a soil crust to form.

- Typically, the soil immediately below the surface layer is loose.

- Crusts: restrict seedling emergence; reduce oxygen diffusion to seedlings; reduce surface water evaporation; increase wind erosion in those soils that have an appreciable amount of sand.



## C.3.3. Soil Drainage Classes

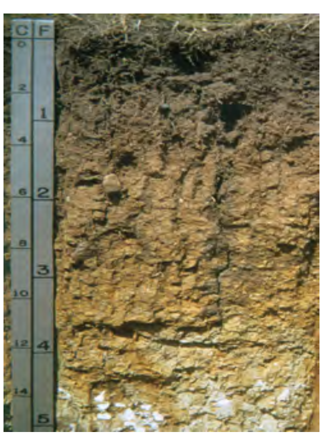
**Soil drainage classes** refer to subsurface or internal drainage of water through the soil profile.

- 4 main drainage classes
  - ➢ Well drained
  - ➢ Moderately well drained
  - ➢ Somewhat poorly drained
  - ➢ Poorly drained.

- Also affected by "restrictive layers" and "water table"

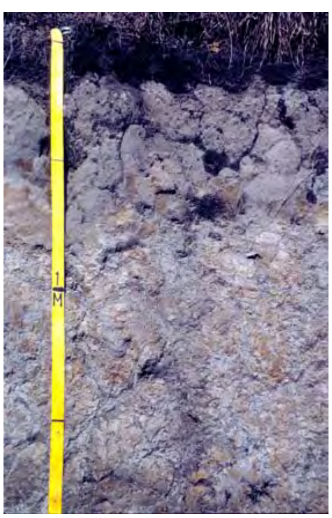
**Well drained** – water is removed from the soil readily, but not rapidly. Internal free water is commonly deep or very deep. Water is available to plants in humid regions during much of the growing season. Wetness does not inhibit root growth. Other characteristics include browner colors, lower clay content and higher sand content (coarse textures), large pore spaces, good aeration. Well drained soils typically do not have any gray mottles or colors (chroma $\leq 2$) in the upper 40 inches of the soil profile.

**Moderately well drained** – water is removed from the soil somewhat slowly during some periods of the year. Internal water is moderately deep. The soil is wet for only a short period of time within the rooting depth during the growing period, but long enough that most crops are affected. Other features include have a zone or horizon free of gray colors or mottles in the upper 20 inches of the soil profile. Depth to apparent wetness (chroma $\leq 2$ color) is within 40 inches of the surface.



**Somewhat poorly drained** – the soil is wet at a shallow depth for significant periods during the growing season. Internal free water is commonly shallow. Unless the soil is artificially drained (with pipes and ditches) the growth of most plants is restricted. Other features include having no zones without gray colors or mottles in the upper portion of the profile. Within the upper 10 inches of the soil profile, gray zones (chroma $\leq 2$) should be LESS that 50% of the total colors . Typically have 50% or more gray colors or mottles (chroma $\leq 3$) within 10-30 inches of the soil surface.

**Poorly drained** – the soil is wet at shallow depth during the growing season or remains wet for long periods of time. Unless the soil is artificially drained, most crops cannot be grown. The soil may or may not be wet directly below the A horizon. It has gray or gleyed colors, fine, small pore spaces, poor aeration, possibly saturated with water, or ponded water on surface. Dominant (>50%) gray colors or mottles (chroma $\leq 2$) within the upper 10 inches of the soil profile.



A chroma of $\leq 2$ (color) in the surface (or near-surface) layer may not reliably indicate a soil wetness condition because the low chroma is sometimes a natural feature. For instance, E horizons result from the eluviation (leaching) of iron oxides and clay, not necessarily the reduction and depletion of iron caused by saturation and anaerobic conditions.

**Factors affecting drainage**:

- Permeability
- Pore space
- Texture
- Organic matter
- Landscape position

**Landscape Positions**

Landscape position causes local changes in moisture and temperature. When rain falls on a Landscape, water begins to move downward by the force of gravity, either through the soil or across the surface to a lower elevation. In an area where climate, living organisms, parent material, and time are held constant, the drier upslope soils may be quite different from the wetter soils at the base of the slope, where water accumulates. The wetter soils may have reducing conditions that will inhibit proper root growth for plants that require a balance of soil oxygen, water, and nutrients.

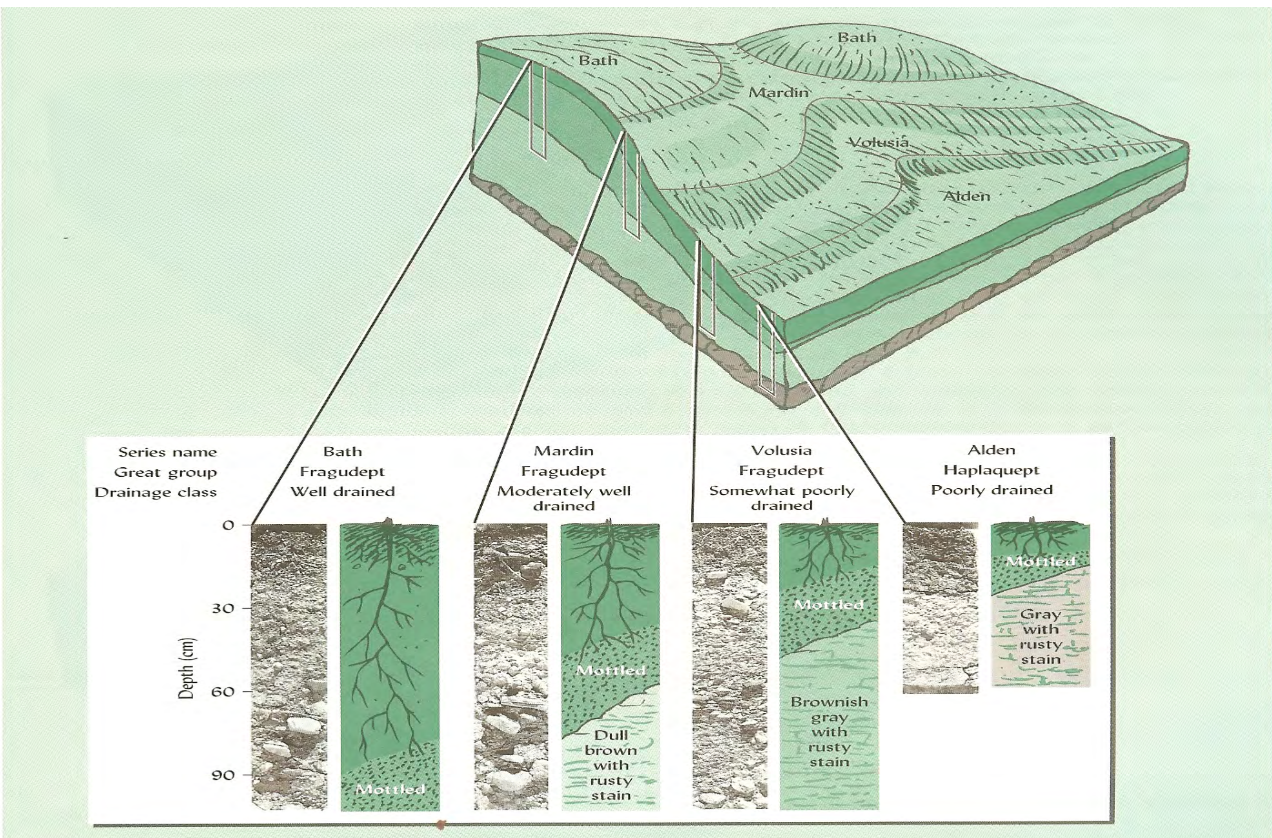



FIGURE 19.3 Profile monoliths of four soils of a drainage catena (below) and a block diagram showing their topographic association in a landscape (above). Note the decrease in the depth of the well-aerated zone (above the mottled layers) from the Bath (well-drained, upslope) to the Alden (poorly drained, downslope). The Alden soil remains wet throughout the growing season. These soils are all developed from the same parent material and differ only in drainage and topography. All four soils belong to the Inceptisols order. With the exception of the cultivated Volusia, the monoliths shown were taken from forested sites. [Based on Cline and Marshall (1977)]

(from: Brady and Weil Nature and Property of Soils,12th ed. 1999)

## Basic Chemical Properties

- Soil minerals have chemical properties, as well as physical properties. The unique chemistry of soil is indispensable for human existence on earth, because these chemicals, one or the other, maintain the cyclic food chain through the plants and connect the human life constantly with this cycle.

- In general, the soil chemistry always deals with the various aspects of solution and solid phase chemistry. Thus the contact area between the liquid phase and the solid phase is of immense importance in the chemistry of soil, which naturally deals with the colloids.

- Two of major soil chemical properties are Soil pH and Cation exchange capacity.

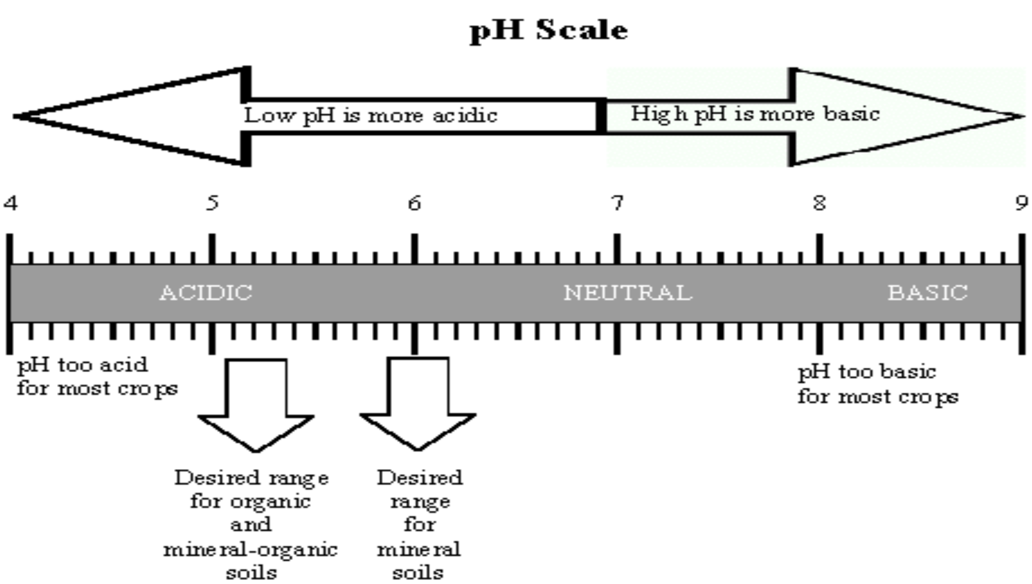
**D. Soil pH**

- Soil pH is the measure of the acidity or basicity in soils.

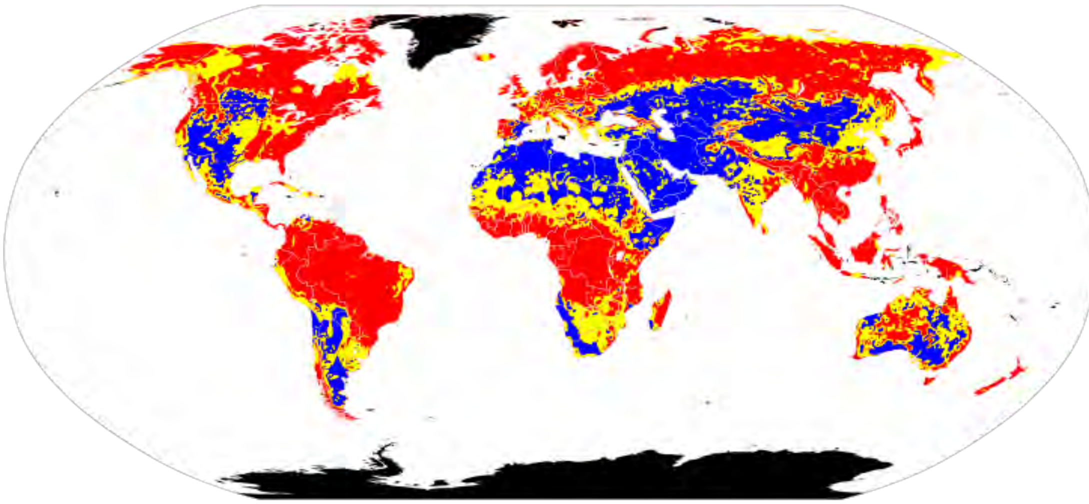
  Definition. pH is defined as the negative logarithm (base 10) of the activity of hydrogen ions(H+) in solution. It ranges from 0 to 14, with 7 being neutral.
  - A pH below 7 is acid
  - A pH above 7 is basic or alkaline
  -

- Significance. Soil pH is considered a master variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrients availability by controlling the chemical forms of the nutrient. Affects all soil properties: physical, chemical, biological.

- The optimum PH range for most plants is between 6 and 7.5, however many plants have adapted to thrive at pH values outside this range.



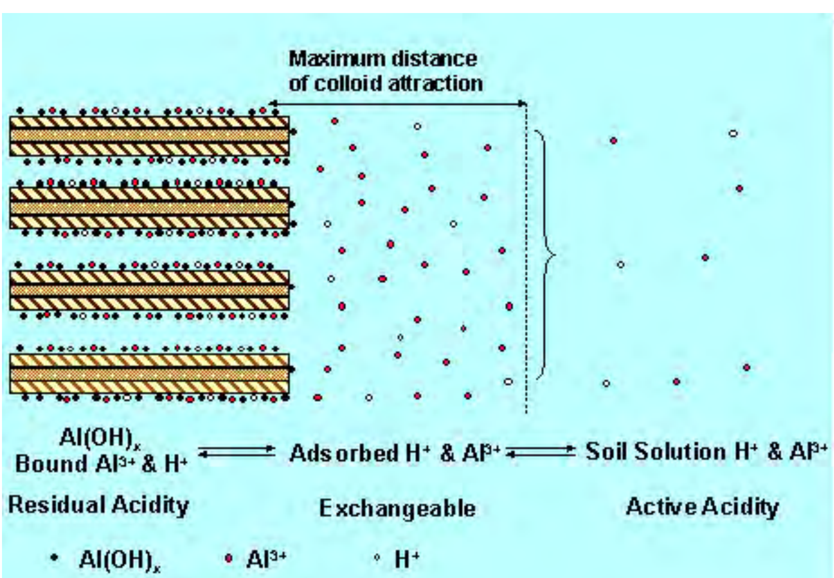
**General pH of the world's soils**



Acidic pH  Basic pH  Neutral pH  No data

## D.1. Soil Acidity

Acidity in soils comes from $H^+$ and $Al^{3+}$ ions in the soil solution and adsorbed to soil surfaces. While pH is the measure of $H^+$ in solution, $Al^{3+}$ is important in acid soils because between pH 4 and 6, $Al^{3+}$ reacts with water ($H_2O$) forming $AlOH^{2+}$, and $Al(OH)_2^+$, releasing extra $H^+$ ions. Every $Al^{3+}$ ion can create 3 $H^+$ ions. Many other processes contribute to the formation of acid soils including rainfall, fertilizer use, plant root activity and the weathering of primary and secondary soil minerals.



- Rainfall: Acid soils are most often found in areas of high rainfall. Excess rainfall leaches base cation from the soil, increasing the percentage of $Al^{3+}$ and $H^+$ relative to other cations. Additionally, rainwater has a slightly acidic pH of 5.7 due to a reaction with $CO_2$ in the atmosphere that forms carbonic acid.

- Fertilizer use: Ammonium ($NH_4^+$) fertilizers react in the soil in a process called nitrification to form nitrate ($NO_3^-$), and in the process release $H^+$ ions.

- Plant root activity: Plants take up nutrients in the form of ions ($NO_3^-$, $NH_4^+$, $Ca^{2+}$, $H_2PO_4^-$, etc.), and often, they take up more cations than anions. However plants must maintain a neutral charge in their roots. In order to compensate for the extra positive charge, they will release $H^+$ ions from the root. Some plants will also exude organic acids into the soil to acidify the zone around their roots to help solubilize metal nutrients that are insoluble at neutral pH, such as iron (Fe).
- Weathering of minerals: Both primary and secondary minerals that compose soil contain Al. As these minerals weather, some components such as Mg, Ca, and K, are taken up by plants, others such as Si are leached from the soil, but due to chemical properties, Fe and Al remain in the soil profile. Highly weathered soils are often characterized by having high concentrations of Fe and Al oxides.

- Acid Rain: When atmospheric water reacts with sulfur and nitrogen compounds that result from industrial processes, the result can be the formation of sulfuric and nitric acid in rainwater. However the amount of acidity that is deposited in rainwater is much less, on average, than that created through agricultural activities.

- Mine Spoil: Severely acidic conditions can form in soils near mine spoils due to the oxidation of pyrite.

## Acid affected soils

- Plants grown in acid soils can experience a variety of symptoms including Al, H, and/or Mn toxicity, as well as potential nutrient deficiencies of Ca and Mg.
- Al toxicity is the most widespread problem in acid soils. Al is present in all soils, but dissolved $Al^{3+}$ is toxic to plants; $Al^{3+}$ is most soluble at low pH, above pH 5.2 little aluminum is in soluble form in most soils.
- Al is not a plant nutrient, and as such, is not actively taken up by the plants, but enters plant roots passively through osmosis. Al damages roots in several ways: In root tips and
- Al interferes with the uptake of Ca, an essential nutrient, as well as bind with phosphate and interfere with production of ATP and DNA, both of which contain phosphate. Al can also restrict cell wall expansion causing roots to become stunted.

- Below pH 4, $H^+$ ions themselves damage root cell membranes.

- In soils with high content of Manganese (Mn) containing minerals, Mn toxicity can become a problem at pH 5.6 and below. Mn, like aluminum, becomes increasingly more soluble as pH drops, and Mn toxicity symptoms can be seen at pH's below 5.6. Mn is an essential plant nutrient, so plants transport Mn into leaves. Classic symptoms of Mn toxicity are crinkling or cupping of leaves.

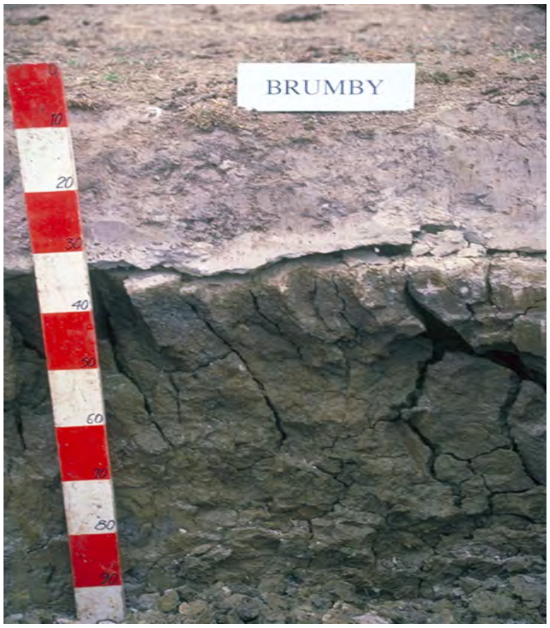
## D. 2. Sources of Basicity

- Basic soils have a high saturation of base cations ($K^+$, $Ca^{2+}$, $Mg^{2+}$ and Na+). This is due to an accumulation of soluble salts are classified as either saline soil, sodic soil, saline-sodic soil or alkaline soil.

- All saline and sodic soils have high salt concentrations, with saline soils being dominated by Ca and Mg salts and sodic soils being dominated by Na. Alkaline soils are characterized by the presence of carbonates.

**Alkalinity and Sodium Problems**

- Soil can become alkaline naturally or it can be made alkaline by water used for irrigation. Highly alkaline, high pH irrigation water has elevated levels of carbonates (CO3-) and bicarbonates (HCO3-). These combine with calcium and other cations adsorbed to soil minerals, which is replaced by sodium cations. The sodium adsorbed to the soil particles causes the particles to repel one another and disperses or disaggregates the peds. Soil structure is lost so that roots and water do not penetrate soil. (See soil profile below.)



## D.3. Nutrient availability in relation to soil pH

- Plant nutrient availability is controlled by soil pH.
- Nutrients needed in the largest amount by plants are referred to as **macro-nutrients** and include **nitrogen (N), phosphorus (P), and potassium (K), calcium (Ca), Magnesium (Mg) and Sulphur (S).**
- Plants also need **trace nutrients** or **micro-nutrients**. Trace nutrients are not major components of plant tissue, but are required for growth. These include **Iron, (Fe), manganese (Mn), zinc (Zn), copper (Cu), Cobalt (Co), Molybdenum (Mo), and Boron (Bo)**.
- In slightly-to-moderately alkaline soils, Mo and macro-nutrient (except P) availability is increased, but P, Fe, Mn, Zn Cu, and Co levels are reduced so low they may affect plant growth.
- In acid soils, micro-nutrient availability (except Mo and Bo) is increased. Nitrogen is supplied as ammonium ($NH_4$) or nitrate ($NO_3$) in fertilizer amendments, and dissolved N will have the highest concentrations in soil with pH 6-8. Concentrations of available N are less sensitive to pH than concentration of available P.
- In order for P to be available for plants, soil pH needs to be in the range 6.0 and 7.5. If pH is lower than 6, P starts forming insoluble compounds with iron (Fe) and aluminium (Al) and if pH is higher than 7.5 P starts forming insoluble compounds with calcium (Ca).
- Most nutrient deficiencies can be avoided between a pH range of 5.5 to 6.5, provided that soil minerals and organic matter contain the essential nutrients to begin with.

## D. 4. Increasing pH of acidic soil

- The most common amendment to increase soil pH is lime ($CaCO_3$ or $MgCO_3$), usually in the form of finely ground agricultural lime. The amount of lime needed to change pH is determined by the mesh size of the lime (how finely it is ground) and the **buffering capacity** of the soil. A high mesh size (60 - 100) indicates a finely ground lime, that will react quickly with soil acidity.
- **Buffering capacity** of soil is a function of a soil's cation exchange capacity, which is in turn determined by the clay content of the soil, the type of clay and the amount of organic matter present.
    - Soils with high clay content, particularly shrink- swell clay, will have a higher buffering capacity than soils with little clay.
    - Soils with high organic matter will also have a higher buffering capacity than those with low organic matter.

- Soils with high buffering capacity require a greater amount of lime to be added than a soil with a lower buffering capacity for the same incremental change in pH.

- Other amendments that can be used to increase the pH of soil include wood ash, industrial CaO (burnt lime), and oyster shells. White firewood ash includes metal salts which are important for processes requiring ions such as Na+ (Sodium), K+ (Potassium), Ca2+ (Calcium), which may or may not be good for the select flora, but decreases the acidic quality of soil.

- These products increase the pH of soils through the reaction of $CO_3^{2-}$ with $H^+$ to produce $CO_2$ and $H_2O$. Calcium silicate neutralizes active acidity in the soil by removing free hydrogen ions, thereby increasing pH. As its silicate anion captures $H^+$ ions (raising the pH), it forms monosilicic acid ($H_4SiO_4$), a neutral solute.

**<u>Decreasing pH of basic soil</u>**

- Decreasing the pH of a basic soil can be done by means of adding acidic amendments:

- Iron sulphates or aluminum sulphate as well as elemental sulfur (S) reduce pH through the formation of sulfuric acid.

- Urea, urea phosphate, ammonium nitrate, ammonium phosphates, ammonium sulphate and mono potassium phosphate fertilizers.

- Plant litter, compost, and manure will decrease soil pH through the decomposition process. Certain acid organic matter such as pine needles, pine sawdust and acid peat are effective at reducing pH.

## E. Cation-exchange capacity

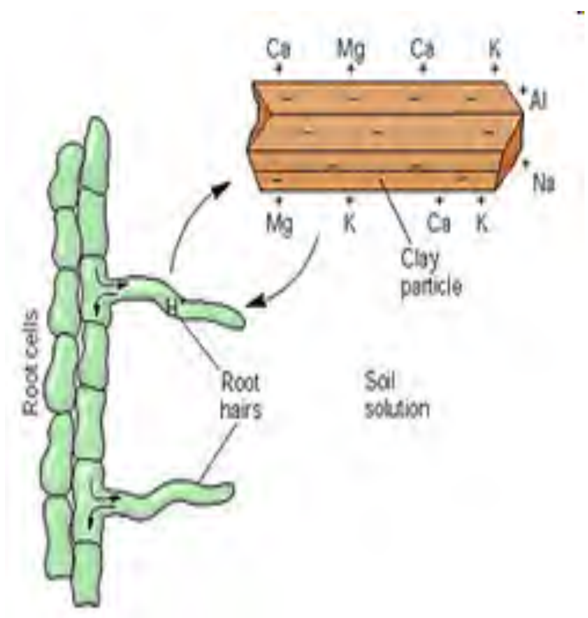
- **Cation** – a positively charged ion; is attracted to a negative charge
- Example: think of a magnet – opposite charges attract
- **Cation Exchange** – The interchange between a cation in solution and another cation on the surface of any surface-active material, such as clay or organic matter
- **Cation Exchange Capacity** – The sum total of exchangeable cations that a soil can adsorb. Expressed in centimoles of charge per kilogram ($cmol_c/kg$) of soil

Definition. In soil science, **cation-exchange capacity** (CEC) is the maximum quantity of total cations, of any class, that a soil is capable of holding, at a given pH value, for exchanging with the soil solution.

Significance. CEC is used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination. It is expressed as milliequivalent of hydrogen per 100 g (meq+/100g), or centi mol per kg (cmol+/kg). The numeric expression is coincident in both units.

Clay and humus have electrostatic surface charges that attract the solution ions, and hold them. This holding capacity varies for the different clay types and clay-blends present in soil, and is very dependent of the proportion of clay+humus that is present in a particular soil. A way to increase CEC is to favor the formation of humus. For agricultural soils, CEC is ideally between 10 and 30 meq/100 g.

**Cation and plant root interaction**



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United States Department of Agriculture

# The 12 Orders of Soil Taxonomy

## Alfisols

Alfisols are in semiarid to moist areas.

These soils result from weathering processes that leach clay minerals and other constituents out of the surface layer and into the subsoil, where they can hold and supply moisture and nutrients to plants. They formed primarily under forest or mixed vegetative cover and are productive for most crops.

**Alfisols make up about 10% of the world's ice-free land surface.**

## Andisols

Andisols form from weathering processes that generate minerals with little orderly crystalline structure. These minerals can result in an unusually high water- and nutrient-holding capacity.

As a group, Andisols tend to be highly productive soils. They include weakly weathered soils with much volcanic glass as well as more strongly weathered soils. They are common in cool areas with moderate to high precipitation, especially those areas associated with volcanic materials.

**Andisols make up about 1% of the world's ice-free land surface.**

## Aridisols

Aridisols are soils that are too dry for the growth of mesophytic plants. The lack of moisture greatly restricts the intensity of weathering processes and limits most soil development processes to the upper part of the soils. Aridisols often accumulate gypsum, salt, calcium carbonate, and other materials that are easily leached from soils in more humid environments.

Aridisols are common in the deserts of the world.

**Aridisols make up about 12% of the world's ice-free land surface.**

## Entisols

Entisols are soils that show little or no evidence of pedogenic horizon development.

Entisols occur in areas of recently deposited parent materials or in areas where erosion or deposition rates are faster than the rate of soil development; such as dunes, steep slopes, and flood plains. They occur in many environments.

**Entisols make up about 16% of the world's ice-free land surface.**

## Gelisols

Gelisols are soils that have permafrost near the soil surface and/or have evidence of cryoturbation (frost churning) and/or ice segregation.

Gelisols are common in the higher latitudes or at high elevations.

**Gelisols make up about 9% of the world's ice-free land surface.**

## Histosols

Histosols have a high content of organic matter and no permafrost. Most are saturated year round, but a few are freely drained. Histosols are commonly called bogs, moors, peats, or mucks.

Histosols form in decomposed plant remains that accumulate in water, forest litter, or moss faster than they decay. If these soils are drained and exposed to air, microbial decomposition is accelerated and the soils may subside dramatically.

**Histosols make up about 1% of the world's ice-free land surface.**

## Inceptisols

Inceptisols are soils of semiarid to humid environments that generally exhibit only moderate degrees of soil weathering and development.

Inceptisols have a wide range in characteristics and occur in a wide variety of climates.

**Inceptisols make up about 17% of the world's ice-free land surface.**

## Mollisols

Mollisols are soils that have a dark colored surface horizon relatively high in content of organic matter. The soils are base rich throughout and therefore are quite fertile.

Mollisols characteristically form under grass in climates that have a moderate to pronounced seasonal moisture deficit. They are extensive soils on the steppes of Europe, Asia, North America, and South America.

**Mollisols make up about 7% of the world's ice-free land surface.**

## Oxisols

Oxisols are highly weathered soils of tropical and subtropical regions. They are dominated by low activity minerals, such as quartz, kaolinite, and iron oxides. They tend to have indistinct horizons.

Oxisols characteristically occur on land surfaces that have been stable for a long time. They have low natural fertility as well as a low capacity to retain additions of lime and fertilizer.

**Oxisols make up about 8% of the world's ice-free land surface.**

## Spodosols

Spodosols formed from weathering processes that strip organic matter combined with aluminum (with or without iron) from the surface layer and deposit them in the subsoil. In undisturbed areas, a gray eluvial horizon that has the color of uncoated quartz overlies a reddish brown or black subsoil.

Spodosols commonly occur in areas of coarse-textured deposits under coniferous forests of humid regions. They tend to be acid and infertile.

**Spodosols make up about 4% of the world's ice-free land surface.**

## Ultisols

Ultisols are soils in humid areas. They formed from fairly intense weathering and leaching processes that result in a clay-enriched subsoil dominated by minerals, such as quartz, kaolinite, and iron oxides.

Ultisols are typically acid soils in which most nutrients are concentrated in the upper few inches. They have a moderately low capacity to retain additions of lime and fertilizer.

**Ultisols make up about 8% of the world's ice-free land surface.**

## Vertisols

Vertisols have a high content of expanding clay minerals. They undergo pronounced changes in volume with changes in moisture. They have cracks that open and close periodically, and that show evidence of soil movement in the profile.

Because they swell when wet, vertisols transmit water very slowly and have undergone little leaching. They tend to be fairly high in natural fertility.

**Vertisols make up about 2% of the world's ice-free land surface.**

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**Major Soil Orders Text from Poster**

**Alfisol** result from weathering process that leach clay minerals and other constituents out of the surface layer and into the subsoil well-developed argillic horizon (Bt horizon). It has Base saturation of 35% or greater, indicating relatively fertile, nutrient-rich soils with available calcium, magnesium, potassium, and sodium. This high base saturation means they aren't heavily leached like as Ultisols. ALFISOLS MAKE UP ABOUT 10% OF THE WORLD'S ICE-FREE LAND SURFACE.

**Andisols** form from weathering processes that generate minerals with little orderly crystalline structure. These minerals can result in an unusually high water- and nutrient-holding capacity. As a group, Andisols tend to be highly productive soils. They include weakly weathered soils with much volcanic glass as well as more strongly weathered soils. They are common in cool areas with moderate to high precipitation, especially those areas associated with volcanic materials. ANDISOLS MAKE UP ABOUT 1 % OF THE WORLD'S ICE-FREE LAND SURFACE.

**Aridisols** are soils that are too dry for the growth of mesophytic plants. The lack of moisture greatly restricts the intensity of weathering processes and limits most soil development processes to the upper part of the soils. Aridisols often accumulate gypsum, salt, calcium carbonate, and other materials that are easily leached from soils in more humid environments. Aridisols are common in the deserts of the world. ARIDISOLS MAKE UP ABOUT 12% OF THE WORLD'S ICE·FREE LAND SURFACE.

**Entisols** are young soils that show little or no evidence of pedogenic horizon development. Entisols occur in areas of recently deposited parent materials or in areas where erosion or deposition rates are faster than the rate of soil development; such as dunes, steep slopes, and flood plains. They occur in many environments. ENTISOLS MAKE UP ABOUT 16% OF THE WORLD'S ICE·FREE LAND SURFACE.

**Gelisols** are cold soils that have permafrost near the soil surface and/or have evidence of cryoturbation (frost churning) and/or ice segregation. Gelisols are common in the higher latitudes or at high elevations. GEUSOLS MAKE UP ABOUT 9% OF THE WORLD'S ICE·FREE LAND SURFACE.

**Histosols** have a high content of organic matter and no perma- frost. Most are saturated year round, but a few are freely drained. Histosols are commonly called bogs, moors, peats, or mucks. Histosols form in decomposed plant remains that accumulate in water, forest litter, or moss faster than they decay. If these soils are drained and exposed to air, microbial decomposition is accelerated and the soils may subside dramatically. HISTOSOLS MAKE UP ABOUT 1 % OF THE WORLD'S ICE·FREE LAND SURFACE.

I**nceptisols** show the beginning of horizon formation that generally exhibit only moderate degrees of soil weathering and development. Inceptions often have a cambic (Bw) horizon, subsurface layer showing just initial color/structure changes from the parent material. INCEPTISOLS MAKE UP ABOUT 17% OF THE WORLD'S ICE-FREE LAND SURFACE.

**Mollisols** are characterized by having thick, dark surface layer (mollic epipedon) that has a high base saturation (over 50%), meaning it's rich in essential nutrient cations like calcium, magnesium, potassium, and sodium, indicating fertile, base-rich conditions, contrasting with more acidic soils. These soils are highly fertile. Mollisols are characteristically form under grassland conditions. MOLUSOLS MAKE UP ABOUT 7% OF THE WORLD'S ICE-FREE LAND SURFACE.

**Oxisols** are highly weathered soils of tropical and subtropical regions. They are dominated by low activity minerals, such as quartz, kaolinite, and iron oxides. They tend to have indistinct horizons. Oxisols characteristically occur on land surfaces that have been stable for a long time. They have low natural fertility as well as a low capacity to retain additions of lime and fertilizer. OXISOLS MAKE UP ABOUT 8% OF THE WORLD'S ICE-FREE LAND SURFACE.

**Spodosols** are formed from weathering processes that strip organic matter combined with aluminum (with or without iron) from the surface layer and deposit them in the subsoil. In undisturbed areas, a gray eluvial horizon that has the color of uncoated quartz overlies a reddish brown or black subsoil. Spodosols commonly occur in areas of coarse-textured deposits under coniferous forests of humid regions. They tend to be acid and infertile. SPODOSOLS MAKE UP ABOUT 4% OF THE WORLD'S ICE-FREE LAND SURFACE.

**Ultisols** are formed from fairly intense weathering and leaching processes that result in a well-developed argillic horizon (Bt horizon). Ultisols have base saturations less than 35%. They are typically acid soils in which most nutrients are concentrated in the upper few inches. ULTISOLS MAKE UP ABOUT 8% OF THE WORLD'S ICE-FREE LAND SURFACE.

**Vertisols** have a high content of expanding clay minerals. They undergo pronounced changes in volume (shrink and swell) with changes in moisture. They have cracks that open and close periodically, and that show evidence of soil movement in the profile. Because they swell when wet, vertisols transmit water very slowly and have undergone little leaching. They tend to be fairly high in natural fertility. VERTISOLS MAKE UP ABOUT 2% OF THE WORLD'S ICE·FREE LAND SURFACE.



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# HEALTHY SOILS ARE: *high in organic matter.*

## Losing Organic Matter

Organic matter is vital to healthy soils, yet most modern agricultural operations are not managed in ways to retain high levels. Only half the original organic matter remains in most modern cultivated soils. In general, organic matter levels have fallen from 5-6 percent of the soil to less than 3 percent on most cropland soils.

Using tillage depletes organic matter. Each time the soil is tilled, oxygen is stirred into it, stimulating microbial action to decompose organic matter at an accelerated rate. As a matter of fact, when a woodland is cleared and planted or a prairie is plowed, most of the organic matter that was built over hundreds of years is lost within 10 years of tillage.

Combining frequent tillage with farming practices that leave little plant residue for soil microbes to eat (such as burning or removing crop residues) will lead to the depletion of organic matter.

unlock the SECRETS IN THE SOIL

## ORGANIC MATTER *matters*. IN FACT, THERE MAY BE NO OTHER COMPONENT THAT'S MORE IMPORTANT TO A HEALTHY SOIL THAN ORGANIC MATTER.

The tiny fraction of soil composed of anything and everything that once lived—organic matter—is more than an indicator of healthy soils.

The carbon in organic matter is the main source of energy for the all-important soil microbes and is also the key for making nutrients available to plants. The list of positive influences high levels of organic matter have on healthy soils includes:

1. Provides a carbon and energy source for soil microbes
2. Stabilizes and holds soil particles together
3. Supplies, stores, and retains such nutrients as nitrogen, phosphorusand sulfur
4. Improves the soil's ability to store and move air and water
5. Contributes to lower soil bulk density and less compaction
6. Makes soil more friable, less sticky, and easier to work
7. Retains carbon from the atmosphere and other sources
8. Reduces the negative environmental effects of pesticides, heavy metals and other pollutants
9. Improves soil tilth in surface horizons
10. Increases water infiltration rates
11. Reduces crusting
12. Reduces water runoff
13. Encourages plant root development and penetration
14. Reduces soil erosion

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# HEALTHY SOILS ARE: *high in organic matter.*

Considering the long list of benefits organic matter has on soil health and crop production, increasing organic matter may well be the most important management step a producer can take to improve a farm's profitability and sustainability.  In general, there are three ways to do that:

1. Increase the amount of plant and root production;
2. apply carbon-rich materials to the soil; and
3. use practices that slow rather than speed decomposition.

Cover crops, green manure crops, and perennial forage crops add organic matter, as do compost and manure. Growing crops and roots add biomass above and below the soil surface. However, not all that biomass is converted to soil organic matter—much of it is released as carbon dioxide and water. It can take 20,000 pounds of organic inputs such as crop residue to increase the actual soil organic matter from 4 percent to 5 percent.

Compost in particular breaks down more slowly and improves soil structure more quickly than other organic materials. Manure breaks down quickly to add nutrients for crops, but takes longer to improve the soil than compost.

## COMPARING ACTIVE AND STABILIZED ORGANIC MATTER

| | PORTION OF ALL ORGANIC MATTER | DECOMPOSITION TIME | FUNCTIONAL IMPORTANCE |
|---|---|---|---|
| **ACTIVE** | One-half to two-thirds | Up to several decades | Decomposes organic material to produce plant nutrients |
| **STABILIZED** | One-third to one-half | A century or more | Exceptional water holding capacity, soil structure **benefits; reservoir** for nutrients, including carbon |

**WANT TO LEARN MORE? VISIT WWW.NRCS.USDA.GOV**

## Active and Stabilized Organic Matter

Organic matter can be divided into two categories: active and stabilized. The portion made of fresh organic material and living organisms, as well as partially decomposed material that is slowly decomposing, is called "active organic matter."

Active organic matter and the microbes that feed on it are central to nutrient cycles in the soil. Nutrients, especially nitrogen, phosphorus, and sulfur, are held in this active organic matter until soil organisms release them for plant use.

This accounts for there being much more nutrient volume in the soil than is available for plant use at any one time. For example, a soil with 3 percent organic matter contains about 3,000 pounds per acre of nitrogen, but only a small part of that (30-100 pounds) may become available to plants in any one year, depending on decomposition rates.

While active organic matter may decompose over a few decades, the stabilized portion of organic matter is made of larger, more complex compounds that are much more difficult for microbes to degrade. Much of the stabilized organic matter in the soil is highly decomposed plant and animal tissues that grew more than a century, and possibly several centuries, ago. This organic matter becomes carbon-rich humus that's resistant to further decay.

"Stabilized organic matter" or humus, acts like a sponge and can absorb six times its weight in water. It's also a reservoir for nutrient storage, sequestering carbon from the atmosphere and other sources.

Healthy soils need both active and stabilized organic matter to function well.

Natural Resources Conservation Service

USDA

# HEALTHY SOILS ARE: *well-structured.*

## Give it the Slake Test!

Does your soil have good structure? Give it the slake test! Ray Archuleta, an agronomist with the USDA Natural Resources Conservation Service with a passion for soil health, has done the test scores of times. Anyone can do it, he says, and he predicts it will open your eyes.

"What happens with poor soil structure is that the pores collapse in water and the soil breaks apart," Archuleta says. "Soil with good structure—the untilled soil—can still be intact for the most part even 24 hours later. The reason for the difference is soil structure. Biological cementing, the work of soil microbes, glues the aggregates of the untilled soils together."

In a similar test, an infiltration or rainfall simulation test, Archuleta puts the two soil samples in wire mesh inserted into empty jars, then simulates rainfall onto them.

"When you put a tilled soil and an un-tilled soil in yarn jars and simulate rainfall onto them, you quickly see the untilled soil allows the water to infiltrate the whole profile. On the other hand, water stays on top of the tilled soil much longer," Archuleta says.

*Continued on back*

unlock the SECRETS IN THE SOIL

## "SOFT AND CRUMBLY." "LIKE COTTAGE CHEESE." "LIKE A SPONGE." "LOOSE AND FULL OF HOLES."

Those and other common descriptions of what healthy soil looks and feels like refer to good soil structure.

Soil structure, the arrangement of the solid parts of the soil and the pore space between them, is critical to how the soil functions. When the solid parts—sand, silt and clay particles—cling together as coarse, granular aggregates, the soil has a good balance of solid parts and pore space.

Highly aggregated soils—those granular, durable, distinct aggregates in the topsoil that leave large pore spaces between them—are soils with good tilth and good structure.

Well-structured soils have both macropores (large soil pores generally greater than 0.08 mm in diameter) and micropores (small soil pores with diameters less than 0.08 mm that are usually found within structural aggregates).

An interconnected network of pores associated with loosely packed, crumbly, highly aggregated soils allows rapid infiltration and easy movement of both water and air through the soil and provides habitat for soil organisms.

Chemical and physical factors play a prominent role in small aggregate formation in clay soils, while biological processes drive development of large aggregates and macropores. Earthworms, for instance, produce both new aggregates and pores. Their binding agents are responsible for the formation of water-stable, macro-aggregates, and their burrowing creates continuous pores linking surface to subsurface soil layers. As they feed, earthworms also speed plant residue decomposition, nutrient cycling, and redistribution of nutrients in the soil profile.

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# HEALTHY SOILS ARE: *well-structured.*

Soil organic matter also helps develop stable soil aggregates. Soil microorganisms that are fed with organic matter secrete a gooey protein called glomalin, an effective short-term cementing agent for large aggregates. Organic glues are produced by fungi and bacteria as they decompose plant residues. Water-resistant substances produced by microorganisms, roots, and other organic matter, provide long-term aggregate stability from a few months to a few years.

## TILAGE DESTROYS STRUCTURE

Management practices that reduce soil cover, disrupt continuous pore space, compact soil, or reduce soil organic matter, negatively impact soil structure. Since tillage negatively affects all of these properties, it's high on the list of practices damaging to healthy soils.

When tillage loosens the soil, it leaves soil particles exposed to the forces of wind and water. Transported by wind and water, detached soil particles settle into pores, causing surface sealing, compaction and reduced infiltration. When this happens less water is available to plants and runoff and erosion increases.

By contrast, soils that are not tilled and are covered with diverse, high residue crops throughout the year have better soil structure, are highly aggregated, with high levels of organic matter and microorganism activity, high water holding capacity, high infiltration rates, and little compaction.

## WANT TO LEARN MORE?

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"I think these tests are powerful visual tools to help explain and help people remember how soils function" Archuleta continues. "I used to think if I tilled the soil—fluffed it up—it would allow more water in. But that's just not true. Tilling soil closes pore space and keeps rainfall from infiltrating. You've got to have pore space in your soil from top to bottom."

"The tests tell me in our watersheds we have an infiltration problem, not a runoff problem," he concludes. "What I mean is, if we focus on building healthy soils that result in more infiltration, we'll do what we need to do to eliminate much of the runoff."

## How to do the Slake Test

The slake test compares two chunks of topsoil in water to see how well and how long they will hold together. Here are the steps:

1. Collect a chunk of topsoil—a size that would fit in your hand—from an area where you don't till, like a fencerow, or a field you've no-tilled or had in grass for many years.
2. Get a second spade-full or chunk of soil from a field you've tilled consistently. It should be the same soil type as the first sample.
3. Find two glass jars, yarn jars or some kind of clear glass jars large enough to hold the chunks of soil.
4. Put together some type of wire mesh that you can hook at the top of each jar that will allow the soil to be submerged in the water, yet be held within the top half of the jar.
5. Insert the wire meshes into each jar.
6. Fill the jars with water.
7. At the same time, submerge the tilled sample in one jar, and the untilled sample in the other.
8. Watch to see which soil holds together and which one falls apart. The soil with poor structure is the one that will begin to fall apart.

## NCF-Envirothon 2026 Mississippi
## Soils and Land Use Study Resources

**Key Topic #3: Soil Ecology**

10. Explain how plants take in nutrients and water, and what soil conditions and characteristics influence this uptake.
11. Explain the interactions of soil with the water cycle, including infiltration, runoff, and reservoirs such as aquifers.
12. Describe the ecosystem services provided by soil, such as water filtration, carbon sequestration, nutrient cycling, etc.
13. Describe how soil type and other soil properties can influence the plant communities found utilizing a particular soil.

| **Resource Title** | **Source** | **Located on Page** |
|---|---|---|
| The Soil Around Us, Chapter 1 | *Mississippi Soils Study Guide for the Mississippi Envirothon** | 76 |
| Essential Nutrients for Plants | *Tony L. Provin and Mark L. McFarland. (2024, May 23). Essential nutrients for plants. Texas A&M AgriLife Extension Service.* *https://agrilifeextension.tamu.edu/library/gardening/essential-nutrients-for-plants/* | 78 |
| Soils Regulate, Partition, and Filter Air and Water, Chapter 3 | *Scheyer, J. M., & Hipple, K. W. (2005). Urban Soil Primer. USDA. Natural Resources Conservation Service.* *https://www.nrcs.usda.gov/sites/default/files/2023-01/Urban-Soil-Primer-Homeowners-and-Renters.pdf* | 80 |
| Grazing Lands Management (Water Cycle) | *USDA NRCS. (2001). Grazing Lands Management Water Cycle. NE Fact Sheet-9 2001* | 85 |
| Forest Soils of Mississippi | *Oldham, L. (n.d.) MSU Extension Publication 2822 (POD-04-24)* *https://extension.msstate.edu/sites/default/files/publications/P2822_web.pdf* | 86 |

**The Soils Around Us: Chapter 1**

Scientifically soils are defined by how they were formed on the earth's surface. In most cases soils are defined as a natural medium on the earth surface that are formed through the interaction of Climate and Living organism on parent material that is suppressed by topography over periods of time. Generally soils are defined by who and how they are used on the earth. Soils are a dynamic entity and are used in numerous ways. Soils are used in agriculture, where they serve as the anchor and primary nutrient base for plants. The type of soil and available moisture determines the species of plants that can be cultivated. Soil material is a critical component in the mining and construction industries. Soil serves as a foundation for most construction projects. The movement of massive volumes of soil can be involved in surface mining, building and dam construction. Earth sheltering is the architectural practice of using soil for external thermal mass against building walls.

Soil resources are critical to the environment, as well as to food and fiber production. Soil provides minerals and water to plants. Soil absorbs rainwater and releases it later, thus preventing floods and drought. Soil cleans the water as it percolates through it. Soil is the habitat for many microorganisms that are active in all biological processes. Above-ground and below-ground biodiversities are tightly interconnected, making soil protection of paramount importance for any restoration or conservation plan. The biological component of soil is an extremely important carbon sink since about 57% of the biotic content is carbon. Poor farming and grazing methods have degraded soils and released much of this sequestered carbon to the atmosphere. Restoring the world's soils could offset some of the huge increase in greenhouse gases causing global warming while improving crop yields and reducing water needs. Waste management often has a soil component as, septic drain field's treat effluent using aerobic soil processes. Landfills use soil for daily cover. Land application of wastewater relies on soil biology to aerobically treat biochemical oxygen demand. Organic soils, especially peat, serve as a significant fuel resource; but wide areas of peat production, such as sphagnum bogs, are now protected because of patrimonial interest. Both animals and humans in many cultures occasionally consume soil. It has been shown that some animals consume soil, together with their preferred food in order to alleviate some forms of toxicities. Soils filter and purify water and affect its chemistry. Rain water and pooled water from ponds, lakes and rivers percolate through the soil horizons and the upper rock strata, thus becoming groundwater. Viruses and pollutants, such as persistent organic pollutants, oils, heavy metals, and excess nutrients are filtered out by the soil. Soil organisms metabolize them or immobilize them in their biomass and necromass, thereby incorporating them into stable humus. Soils directly and indirectly affects all that we do as human beings and as the population of the world rises, more pressure will be put on soils to maintain their function on earth. If soils are to maintain their functions we must continually restore and replenish them for future generations.

**Functions of soil in our ecosystem:**

1) Soil supports the growth of higher plants

- Medium for plant growth
- Supplies nutrient elements essential to plant growth

2) Soil properties are the principal factor controlling the fate of water in the hydrologic system

3) Soil functions as nature's recycling system. Waste products and dead bodies of plants, animals, and people are decomposed and their basic elements are made available for re-use by the next generation of life.

4) Soil provide habitats for many living organisms (mammals, reptiles, insects, bacteria, microscopic cells)

5) Soils are an engineering medium

- Building material, earth fill, bricks
- Foundations for roads, airports, and all buildings.

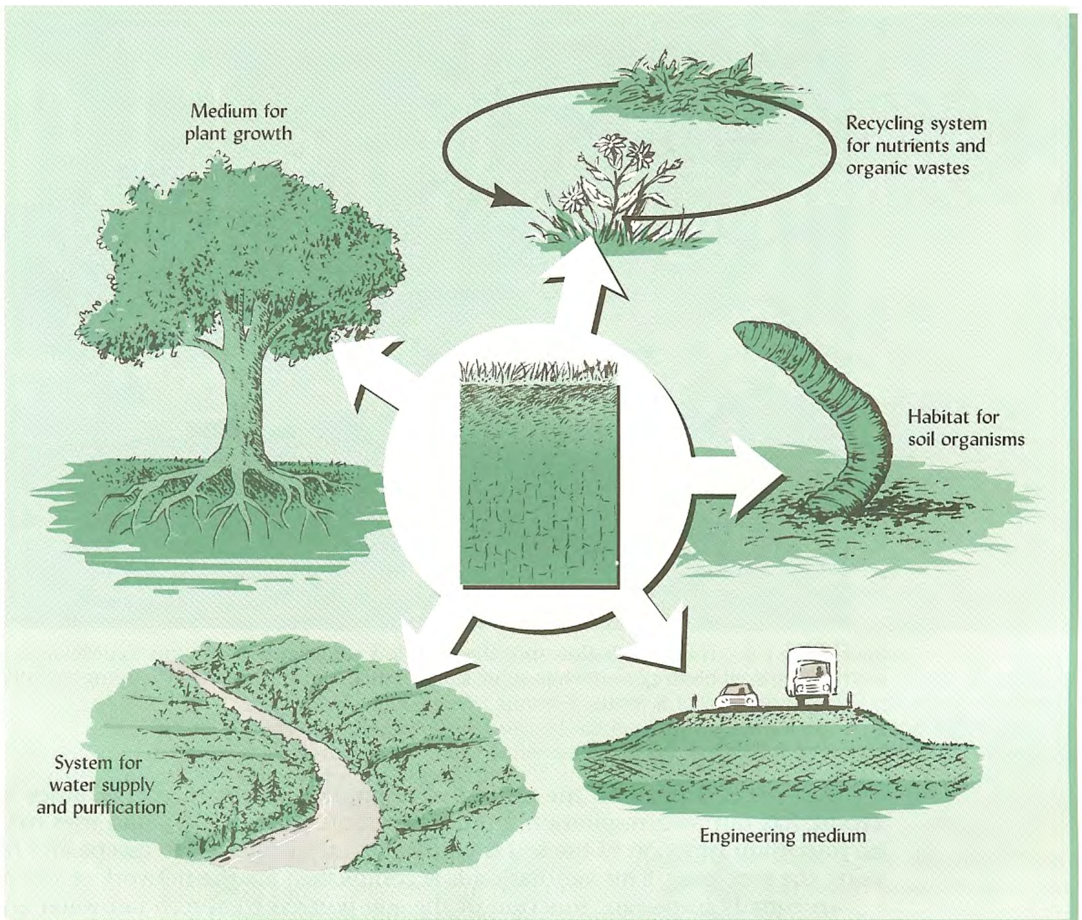


Figure 2 (from: Brady and Weil Nature and Property of Soils, 12th ed. 1999)

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# Essential Nutrients for Plants

**Tony L. Provin** and **Mark L. McFarland***

To be able to grow, develop, and produce at their best, plants must have specific elements or compounds called *plant essential nutrients.*

A plant that lacks an essential nutrient cannot complete its life cycle—the seed may not germinate; the plant may not be able to develop roots, stems, leaves, or flowers properly; or it may not be able to produce seeds to create new plants. Often the plant itself will die.

However, having too much of a nutrient can harm and even kill plants. For example, having too much nitrogen can cause a plant to grow more leaves but less or no fruit. Too much manganese can make the leaves turn yellow and eventually die. And excess boron can kill a plant.

You can save money and effort—and even your plants—if you know what and how much to give your plants. The plants will be healthier and more productive if you give them what they need—no more and no less.

## Plant essential nutrients

Scientists have identified 16 essential nutrients and grouped them according to the relative amount of each that plants need:

- **Primary nutrients,** also known as macronutrients, are those usually required in the largest amounts. They are carbon, hydrogen, nitrogen, oxygen, phosphorus, and potassium.
- **Secondary nutrients** are those usually needed in moderate amounts compared to the primary essential nutrients. The secondary nutrients are calcium, magnesium, and sulfur.
- **Micro-** or **trace nutrients** are required in tiny amounts compared to primary or secondary nutrients. Micronutrients are boron, chlorine, copper, iron, manganese, molybdenum, and zinc.

A very few plants need five other nutrients: cobalt, nickel, silicon, sodium, and vanadium.

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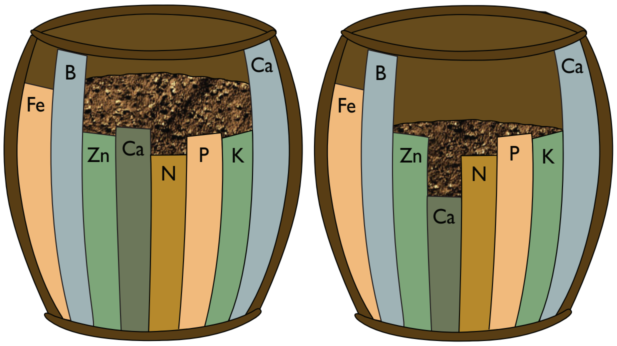


**Figure 1.** Illustration of how nutrients are limiting factors in plant growth. Just as the shortest plank, or stave, of a barrel limits the amount of its contents, so does the amount of a nutrient limit the maximum size or yield of a plant. For the barrel at left, the shortest stave (limiting nutrient) is nitrogen (N); for the barrel at right, the limiting nutrient is calcium (Ca).

Each essential nutrient affects specific functions of plant growth and development (Table 1). Plant growth is limited by the nutrient that is in the shortest supply (Fig. 1).

## Forms of essential plant nutrients

To be used by a plant, an essential nutrient must be broken down into its basic form. The nutrient must be in the form of either a positively charged ion (cation) or a negatively charged ion (anion). A plant cannot use organic compounds, such as those in manure or dead leaves, until they are broken down into their elemental or ionic forms.

Also, plants cannot use an element that is not in the proper form (a specific ion) even if it is present in high concentrations in the soil. For example, the presence of iron (Fe) in the soil will not guarantee that enough of the proper iron ions, $Fe^{2+}$ or $Fe^{3+}$, will be available to the plant.

Plants take in almost all of the essential nutrients through their roots. The exception is carbon, which is taken in through leaf pores, or stomata. Two types of organisms living in the soil help the roots take up nutrients:

- **Microorganisms,** or microbes, break down organic compounds into inorganic compounds in a process called *mineralization.*

- **Fungi** enable some plants to take up phosphorus by increasing the size of the roots and providing more soil-to-root contact.

## Determining available nutrient levels in the soil

It is hard to tell whether the soil has a nutrient problem just by looking at the plants. Symptoms vary by nutrient and plant species. Common symptoms include:

- Little or no growth
- Dead tissue at the leaf tips, on the leaf edges, or within the leaves
- Yellow or dead leaves on one part of the plant only
- Overall leaf yellowing, yellow streaks, or white between the leaf veins

Before spreading any fertilizer—organic or inorganic—check for other possible causes of the problem. Similar symptoms can be caused by diseases, insects, herbicides, compacted soil, and wide changes in soil moisture levels.

To learn whether you need to add nutrients, have the soil tested by an agricultural soil testing laboratory such as the Texas A&M AgriLife Extension Service Soil, Water and Forage Testing Laboratory (http://soiltesting.tamu.edu/). The test results will enable you to apply or avoid applying specific nutrients to ensure that the plants get what they need.

**TABLE 1:** Form, source, mode of uptake and major functions of the 16 plant essential nutrients.

| Nutrient family | Nutrient | Percentage of plant | Form taken up by plants (ion) | Mode of uptake | Major functions in plants |
|---|---|---|---|---|---|
| **Primary** | Carbon | 45 | Carbon dioxide ($CO_2$), bicarbonate ($HCO_3^-$) | Open somates | Plant structures |
| | Oxygen | 45 | Water ($H_2O$) | Mass flow | Respiration, energy production, plant structures |
| | Hydrogen | 6.0 | Water ($H_2O$) | Mass flow | pH regulation, water retention, synthesis of carbohydrates |
| | Nitrogen | 1.75 | Nitrate ($NO_3^-$), ammonium ($NH_4^+$) | Mass flow | Protein/amino acids, chlorophyll, cell formation |
| | Phosphorus | 0.25 | Dihydrogen phosphate ($H_2PO_4^-$, $HPO_4^{2-}$), phosphate ($PO_4^{3-}$) | Root interception | Cell formation, protein syntheses, fat and carbohydrate metabolism |
| | Potassium | 1.5 | Potassium ion (K+) | Mass flow | Water regulation, enzyme activity |
| **Secondary** | Calcium | 0.50 | Calcium ion ($Ca^{2+}$) | Mass flow | Root permeability, enzyme acitivity |
| | Magnesium | 0.20 | Magnesium ion ($Mg^{2+}$) | Mass flow | Chlorophyll, fat formation and metabolism |
| | Sulfur | 0.03 | Sulfate ($SO_4^{2-}$) | Mass flow | Protein, amino acid, vitamin and oil formation |
| **Micro** | Chlorine | 0.01 | Chloride ($Cl^-$) | Root interception | Chlorophyll formation, enzyme activity, cellular development |
| | Iron | 0.01 | Iron ion ($Fe^{2+}$, $Fe^{3+}$) | Root interception | Enzyme development and activity |
| | Zinc | 0.002 | Zinc ion ($Zn^{2+}$) | Root interception | Enzyme activity |
| | Manganese | 0.005 | Manganese ion ($Mn^{2+}$) | Root interception | Enzyme activity and pigmentation |
| | Boron | 0.0001 | Boric acid ($H_3BO_3$), borate ($BO_3^{3-}$), tetraborate ($B_4O_7$) | Root interception | Enzyme activity |
| | Copper | 0.0001 | Copper ion ($Cu^{2+}$) | Mass flow | Enzyme activity |
| | Molybdenum | 0.00001 | Molybdenum ions ($HMoO^{4-}$, $MoO_4^{2-}$) | Mass flow | Enzyme activity and nitrogen fixation in legumes |

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# Chapter 3: Soils Regulate, Partition, and Filter Air and Water

**Figure 3.1**

Soils play a very important role in storing, regulating, and filtering both air and water resources. As rainwater falls onto the soil surface, it may percolate into the soil or run off the surface, depending on soil properties. Soil particles may hold chemicals and nutrients, making them available for plant roots and keeping them from moving into lakes and streams or entering the ground water. Soil pores that hold and transmit air and water play an important role in the health of the soil environment. All living organisms need both air and water. If all soil pores are filled with water or compacted, then less air is available to plant roots. After site preparation or manipulation, the properties of urban soils differ from those of natural soils and the soil air and water react much differently.

**Topics in this chapter:**

- **Soil functions**
- **Urban landscapes**
- **Soil and water interactions**
- **Soil temperature**
- **Stream corridors**
- **Storm water management**
- **Urban wind erosion**

## Soil Functions

The kinds of activities that soils perform are called soil functions. Soil functions help us sort the extremely complex soil system into smaller parts that can be studied and understood. We depend on soil for more than just producing food. Other soil functions include a) providing building materials and support for structures; b) preserving natural and cultural history; c) regulating, partitioning, and filtering air and water; d) sustaining biological diversity and productivity; e) trapping pollutants; and f) providing sites for recreation. Soils perform specific critical functions no matter where they are located, and they perform more than one function at a time (table 3.1).

**Table 3.1: Five Concurrent Soil Functions**

- Soils act like *sponges,* soaking up rainwater and limiting runoff. Soils also impact ground-water recharge and flood-control potentials in urban areas.
- Soils act like *faucets,* storing and releasing water and air for plants and animals to use.
- Soils act like *supermarkets,* providing valuable nutrients and air and water to plants and animals. Soils also store carbon and prevent its loss into the atmosphere**.**
- Soils act like *strainers or filters,* filtering and purifying water and air that flow through them.
- Soils buffer, degrade, immobilize, detoxify, and *trap* pollutants, such as oil, pesticides, herbicides, and heavy metals, and keep them from entering ground-water supplies. Soils also store nutrients for future use by plants and animals above ground and by microbes within the soils.

Soil functions occur in spite of the land use. Rainwater must be dispersed or regulated in urban areas, and landscaping plant roots must have air available for growth. When areas are paved over, plans must be in place to handle rainwater. Buildings constructed on fill material must still be supported by the materials on the site. Soils perform the same or similar functions in all areas, including urban ones.

An important task is convincing people living in the urban environment to consider soil information and data before urban projects begin. This information must be part of the planning process for all urban projects. As soil properties change because of construction or other disturbances, major changes occur in the capacity of a soil to function, as predicted by engineering properties. The ability of a soil to support buildings and other structures changes when the soil is disturbed and/or mixed with other materials. Soil materials placed on top of garbage cannot support large buildings and certain other structures. Thus, it is important to know ahead of time what functional changes are expected to result from soil disturbance. Soil maps and soil profile descriptions can help us to understand how the soil at the building site will respond to project management.

## Urban Landscapes

Landscapes in urban areas are controlled by underlying geologic landforms; by human activities, such as excavation or other disturbances and removal of water, oil, or minerals; and by microrelief in small areas. Soil movement can result from hazards, such as the formation of sinkholes, soil settling, decomposition of buried trees or landfills, and landslides. Some of these hazards are natural in the environment, and others are caused by human activities, such as excavation and filling for building. These impacts are secondary to the intended soil use. Old geologic formations, such as lava flows and lava tubes, collapse and unexpectedly create large holes. Knowing the underlying geologic formations before building can eliminate the need for costly repairs.

Urban planning for landscape changes requires consideration of fill consistency, soil porosity, internal water movement, surface drainage, and the increased water retention as organic matter is added to the soil. Knowledge of landforms helps us to understand water movement and storage whether the landforms were created by geologic forces or human construction. Some human-constructed soil layers dramatically impact water movement in soils. Geologic landforms lie beneath areas of urban development and may not be visible on the landscape (figure 3.2).

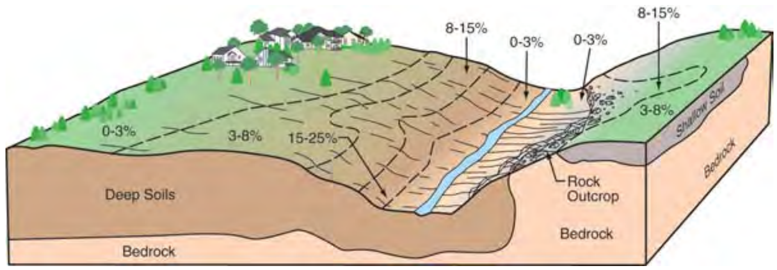


**Figure 3.2: Soil slope and underlying geology.**

**Table 3.2: Summary of Inputs Useful in Identifying Urban Soil-Landscape Units**

| | |
|---|---|
| • Infrastructure | Storm drains, building heights, housing density, and road types |
| • Soil catenas | Interrelated drainage, soil texture, soil depth, and geologic deposits |
| • Block diagrams | Geologic material, relief, and spatial patterns of cuts and fills |
| • Site data | Measured erosion, infiltration, streamflow, and waste filtration |
| • Soil science | Chemical, physical, and biological interactions and discontinuities |
| • Vegetation | Seasonal variation, opportunistic species, and adapted physiology |

## Soil and Water Interactions

Maps with contour lines, called topographic maps, show the direction of waterflow from landforms (figure 3.3). The contour lines are drawn around landforms. Each line represents the same elevation. Contour lines generally show 10- or 20-foot intervals. They run side by side across a slope, and water moves perpendicularly (at a right angle) to the lines to get downhill. The contour lines are closest together where the slope, or downhill gradient, is steepest.

When contour lines form a V shape and elevation increases as you follow the point of the V, the V points upstream. The lines for flat areas or gentle slopes are spaced farther apart than the lines for steeper areas. A closed circle indicates a hilltop or knoll. A closed circle with hatch lines inside indicates a closed depression or sinkhole at the lowest point on a landscape. Map unit symbols on soil survey maps commonly


**Figure 3.3: Topographic map detail.**

indicate the relative steepness of slope. They tie the map unit delineation in soil survey reports to the name of the soil, the texture of its surface layer, and its slope. An example is Ridgebury loam, 3 to 8 percent slopes.

Water tables are underground supplies of water that generally occur closer to the surface during wet periods and are deeper during dry periods. Land use impacts water tables and runoff. An area of wetland may occur where the land surface slopes to an elevation below the water table. Where the underground water does not rise to the surface, it is called an aquifer. Water tables can be identified by observing and recording soil color and soil wetness in urban project excavations or in test holes.

The movement of water into a soil depends heavily on soil texture, soil structure, slope, bulk density, compaction, surface loading, and vegetation. Figures 3.4 and 3.5 demonstrate that more water moves into the soil on natural landscapes than on

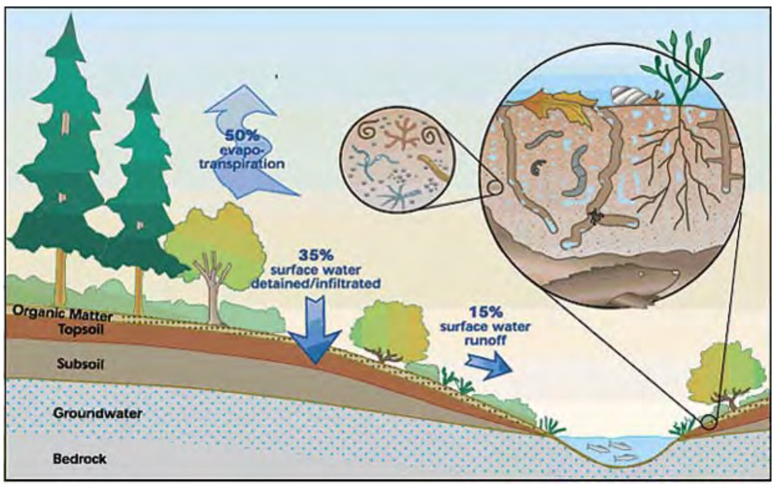


**Figure 3.4: Water movement on a natural landscape with a plant cover. This landscape is in a humid area. In the drier regions, the stream level is higher than the surrounding land.**

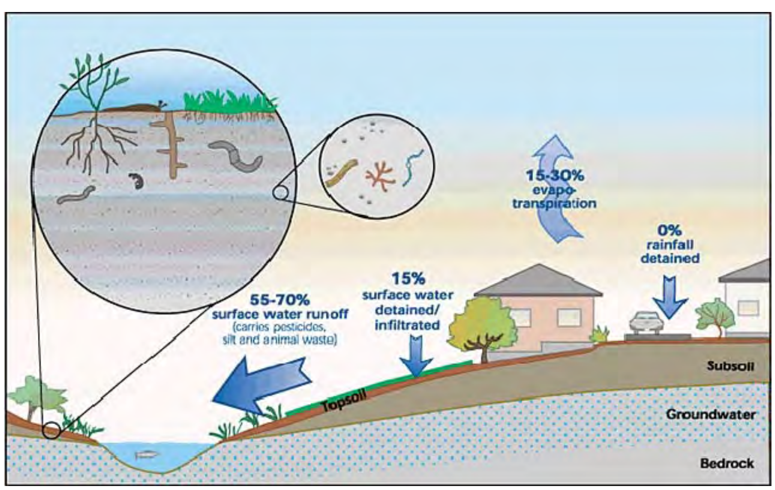


**Figure 3.5: Water movement on a disturbed urban landscape with limited vegetation and impervious surfaces. This landscape is in a humid area. In the drier regions, the stream level is higher than the surrounding land.**

disturbed landscapes, such as those in urban areas. More water evaporates into the air on natural landscapes than in areas covered by streets, roads, homes, garages, and other buildings. More water runs off urban areas because of the impervious nature of pavement, compacted soil layers, and urban buildings. Water containing sediment clogs lakes and reservoirs. Removing this sediment is costly (figure 3.6).

**Figure 3.6: Removing sediment from a flood-control lake. A dam is in the background.**

Oil, gas, lawn fertilizer, pesticides, and other pollutants often run off from urban areas and into lakes, streams, or reservoirs and reduce water quality. Some of the fertilizer, pesticides, and herbicides can run through the soil and into ground water, also impacting urban water quality.

Geologic formations, the kinds of rocks that occur below soils, affect water movement in soils and their landscapes. An example of an unstable geologic formation is a shale bed, which is prone to slippage and landslides (figures 3.7 and 3.8). The weight of excess water in the soil can reduce slope and soil stability, especially in urban areas where expensive urban projects are built.

**Figure 3.7: A home damaged by slippage of shale beds.**

United States
Department of
Agriculture

Natural Resources
Conservation
Service

# *Grazing Lands Management*
# *Water Cycle*

*NE Fact Sheet-9* *December 2001*

## What

The water cycle is the never-ending movement of water from clouds to earth and to clouds again. Influencing those parts of the cycle that affect grassland is important in rangeland management. The cycle begins when precipitation strikes the land, and ends when the water leaves, either through runoff or evaporation. In the interim, livestock producers should store as much water as possible within the soil for use in forage production.

## Why

Water is generally the most limiting factor in rangeland, hayland, and pastureland production. One of three things happens with the moisture that falls as raindrops, snowflakes, sleet or hail: it can be used productively on the site where it fall; it goes downstream as clean water; or, it goes downstream, carrying soil with it. When runoff is dirty, it is taking the land's production potential with it.

## How

**Impact**. When falling raindrops strike bare soil, the impact causes both splash erosion and soil compaction. This results in faster runoff and increased erosion. Good plant cover breaks the force of the raindrops, and allows the water to seep into the soil. The soil can act as a large reservoir, holding moisture, reducing flooding and enhancing water quality. Water stored in the soil promotes a greater and more consistent supply of forage.

**Soil**. Coarse soil takes in water faster than fine soil, but stores less within the root zone of most plants. Water that moves below the root zone of plants recharges groundwater supplies, and sometimes reappears down slope as a spring or creek. Because this movement through the soil is slow, the water supply downstream is cleaner, and stream flow longer than where moisture runs off over the soil surface. Where the surface is bare, less moisture enters the soil and much of the stored water may evaporate during hot, windy days instead of being used for plant growth.

**Plants**. A healthier, more productive grassland water cycle can be achieved by proper grazing. Plants and the litter they produce affect the water cycle in several ways. Plants break the impact of raindrops on the soil surface, and serve as small windbreaks to hod snow. They shade the soil's surface causing it to be cooler creating a better environment for plant growth. Litter acts as a sponge, and slows runoff. This gives moisture more time to move into the soil. Plant roots increase soil porosity so water moves more readily into and through the soil. Roots also hold soil particles in place, reducing erosion. Vigorous plant cover is an important part of influencing the grassland water cycle, and making effective use of precipitation.

## Where to Get Help

For more information about rangeland, hay, and pasture management, contact the local office of the U.S. Department of Agriculture's Natural Resources Conservation Service. It is listed in the telephone directory under "U.S. Government."

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# Forest Soils of Mississippi

People often take the importance of soil for granted. Soils provide the foundation for our homes, cities, and roads, and they also serve as the medium for crops and forests. Soils store and filter the groundwater that nourishes our lives. They provide for the diversity of plants and wildlife that Mississippians depend on for commerce and recreation.

Landowners interested in making the most of their forest need a basic understanding of soils. Forest productivity and the production of wildlife habitat hinge on soil quality. Knowing proper soil management techniques is crucial to conserving the land and protecting watersheds from soil erosion.

## Soil Formation

Soil forms through interactions of physical, chemical, and biological mechanisms on geological materials exposed to the earth's surface. Essentially, soil is the product of weathering from climate and organisms acting upon a geological parent material. These processes are affected by local topography over very long periods of time. Soil takes hundreds to thousands of years to develop in the landscape. This means soil is not a renewable resource, even though crops and forests grown on the soil are.

## Parent Material

Exposed geologic formations provide parent material for the development of soil. The oldest geologic formations in Mississippi occur in the northeast corner of the state. These deposits are from the erosion of what we now call the Appalachian Mountains, and are as much as 250 million years old.

The geology for much of the rest of the state is dominated by the Mississippi Embayment. This trough began to form in the late Cretaceous period, perhaps some 70 million to 80 million years ago. This trough covered much of what is now Mississippi, northern Louisiana, eastern Arkansas, westernmost Tennessee, and north to Cairo, Illinois. The embayment formed an inland sea, extending what we now call the Gulf of Mexico. Over time, this trough was filled by sediments from the erosion of the Appalachian and Ouachita Mountains. As the embayment filled, the earth's crust also rose, and the Mississippi Embayment was transformed into the Gulf States.

The most recent soils of the Mississippi River floodplain formed from sediment during the Ice Age some 1 million years ago and ending 10,000 to 12,000 years ago. The Mississippi River drained immense glacial lakes farther north that formed as the great ice sheets melted. Wind-blown deposits of this glacial outwash formed the Loess Hills bordering the Delta region to the east. Altogether, sedimentary deposits are easier to weather than rock. The most recent alluvial sediments in the Delta are very fertile and are the basis for the success of Mississippi's agricultural industry.

### Climate

Mississippi has a warm, humid climate. Weather patterns are dominated by the continent to the north and the Gulf of Mexico to the south. During the summer, average daytime temperatures are typically in the 80s or 90s. Annual average winter temperatures are in the 40s in the north and 50s along the coast.

Average annual precipitation increases moving southward across the state, with around 50 inches falling in north Mississippi and 65 inches at the coast. The frequency of thunderstorms also increases moving southward, from about 55 days per year in the north to 75 days at the coast.

This warm, humid weather accelerates weathering of parent materials that make up the geology of the state. Weathering involves the biological processes and chemical reactions that transform parent material into soil, which occur faster as the temperature rises.

The soils of the Coastal Plain in southern Mississippi are more weathered than those in river bottomlands. The soils of the river bottoms, including the Mississippi River floodplains, are much more variable than Coastal Plain soils in terms of fertility, degree of weathering, and development. This has implications for agriculture, forestry, and wildlife management.

## Organisms

Mississippi has a great variety of vegetation from north to south and east to west, forming major ecoregions across the state. These areas include the Mississippi Delta, which is dominated by agriculture and bottomland hardwood forests. Forests in the Delta include numerous bottomland species, such as bald cypress, willow oak, swamp chestnut oak, cottonwood, black willow, green ash, sugarberry, and swamp hickory.

To the east of the Delta are the Loess Hills. The vegetation in the Loess Hills region is dominated by cherrybark oak, yellow poplar, water oak, mockernut hickory, and sweetgum. Also, these soils have some of the highest productivity for loblolly pine in the state.

The northern part of the state is within the Upper Gulf Coastal Plain. Vegetation is dominated by oak-pine and oak-hickory forests. Common species here include shortleaf and loblolly pine, upland oaks (such as southern red, white, post, scarlet, black, and blackjack), hickory, and sweetgum.

The Blackland Prairie region has soils with relatively high alkalinity. Vegetation in this region must be tolerant of higher soil pH. Common species are eastern red cedar, post oak, shumard oak, green ash, and hickory.

The Lower Coastal Plain and Northern Gulf of Mexico regions are dominated by upland forests of longleaf pine, slash pine, and upland oaks (such as live oak and southern red oak). Longleaf pine is well-adapted to the frequent, low-intensity fires that burned across this landscape. Slash pine, while tolerant of fire as a mature tree, is less tolerant as a seedling or sapling and is typically confined to wetter sites. Live oak is very hardy and tolerates high winds of tropical storms and saline soils along the coast. Bottomland species in this region include American elm, bald cypress, green ash, sugarberry, water oak, and red maple.

Pine and oak vegetation tend to produce organic acids upon decomposition due to their oleoresins and tannins, respectively. Their decomposition will tend to acidify soils, which further accelerates mineral weathering of geologic sediments.

Prehistoric humans also influenced the Mississippi landscape through fire. As Native American cultures developed agriculture, humans used fire more extensively. This tool was used to clear land for farming and to keep hunting grounds open. Consequently, pre-Columbian civilizations created a mosaic of villages, agricultural fields, and extensive woodland-savannas in Mississippi. Therefore, native vegetation adapted to very frequent burning.

## Topography

The effects of topography on soil formation occur on a smaller, local scale. First, local relief of the land affects internal drainage through the soil. A common observation is that soils on higher positions, such as ridges, are dry, while those in lower positions, such as ravines and wide floodplains, are wet. These differences in drainage will affect the types of chemical reactions involved in weathering of parent material into soil.

Secondly, available moisture has a tremendous influence on the kinds of vegetation growing across the landscape. This, in turn, affects animals living in these areas. Altogether, these differences in plant and animal communities from one area to the next will also influence the weathering of parent materials into soil.

## Time

The floodplains are the youngest, most fertile, and most highly variable soils. Otherwise, soils found in Mississippi tend to be very old. These old soils are highly weathered and lower in nutrients than river bottomlands.

Prehistoric vegetation was very different from today's. However, it still responded to changes in soils and climate. As the last Ice Age was ending, 10,000 to 12,000 years ago, beech, hornbeam, oak, white pine, and hemlock dominated Mississippi forests. Since this vegetation was adapted to cooler climates, weathering processes also changed and slowed.

Yet as vegetation developed on bare ground, organic matter was gradually incorporated into the soil-forming processes. As the climate warmed, forest composition in Mississippi gradually developed to that which is seen today, with the southern pines, oaks, red maple, and sweetgum. Further, organic acids from decaying pine needles and oak leaves accelerated the weathering process.

# Describing Soil Layers

Over time, soil-forming processes transform geological parent material into soil. Intensive weathering occurs near the soil surface. This weathering dissolves and transports minerals downward through the soil. As the minerals move downward, chemical and physical interactions in the soil change, with new minerals created and deposited. This results in the formation of layers, or horizons, in the soil. These layers are characteristic of the geology, hydrology, chemistry, and vegetation on a site. Horizons and their properties are used to describe the soil (Figure 1). Horizons are called O, A, E, B, C, and R.

## O Horizon

The O horizon is on the soil surface and consists of leaves, branches, and other organic materials in varying stages of decomposition. In forests, this horizon is divided into litter and duff layers. While the O horizon is not a part of mineral soil, it is very important. It is in the litter and duff layers that organic material is recycled, with nutrients being returned to the soil through decomposition. These layers also help prevent wind and water erosion of soil particles.

## A Horizon

The A horizon is called topsoil. It is a combination of mineral soil and organic matter that has been incorporated from the litter layer. The topsoil is a zone of leaching, as water moving through the soil washes minerals off soil particles.

## E Horizon

Occasionally, there is a layer beneath the topsoil called the E horizon, which is also a zone of intense leaching. Consequently, this layer is comprised predominantly of washed sand grains. This layer is commonly found in highly weathered soils of the Lower Coastal Plain and Coastal Flatwoods in southern Mississippi.

## B Horizon

The B horizon is the beginning of the subsoil. This is a zone of accumulation, usually of clay minerals or compounds of iron, aluminum, and organic complexes. For many Mississippi soils, the B horizon is generally the next most fertile horizon after the A horizon.

## C Horizon

The C horizon is usually deeper subsoil, considered to be residual parent material from which the soil formed. It bears the effects of weathering but with relatively little influence from soil organisms, as compared to the O, A, E, and B horizons.

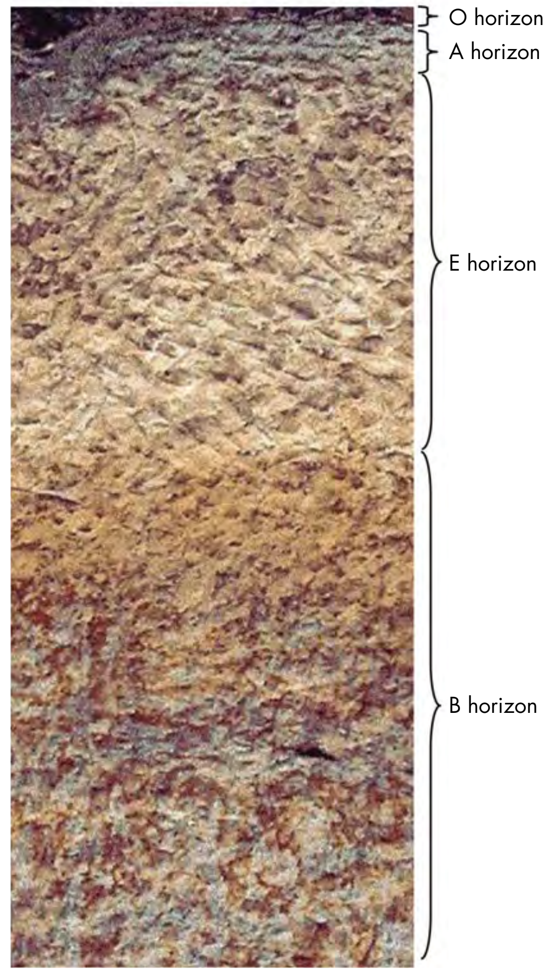



Figure 1. Example of soil horizons.

## R Horizon

The R horizon is found beneath the C horizon and is the original bedrock. In Mississippi, the R horizon is found in soils of the Appalachian foothills, in the northeasternmost corner of the state.

# Soil Properties

There are several soil chemical and physical properties that are important to forest management. They are organic matter, texture, porosity, drainage, and soil pH. These physical and chemical properties of soil interact to determine its fertility. This concept is known as "carrying capacity." Essentially, a given unit of land can produce a set amount of biomass, measured as yield. The following sections include more detailed descriptions of these key soil properties, which are vital to soil fertility.

## Soil Organic Matter

Organic matter is a vital component to soil fertility. Organic matter helps retain plant nutrients and moisture. It also helps development of soil structure, which is how individual soil particles bind together. Good soil structure leads to more and larger pore space, which is necessary for internal drainage and adequate aeration for plant roots. Organic matter decomposes into acidic materials, which further enhance chemical decomposition and weathering of parent material and influence soil acidity.

Plants and animals are the sources for organic matter. Since natural vegetation for most of Mississippi is forest, organic matter often accumulates in litter and duff layers atop mineral soil. Soil organisms such as springtails and millipedes eat and break down the litter layer into finer material that constitutes the duff layer. Other soil organisms, including fungi, microbes, and earthworms, continue decomposition of the duff and further transform organic matter into humus. Eventually, some of the humus is mixed with mineral soil to form the A horizon.

## Soil Texture

Soil texture is the proportion of different particle sizes of soil material. Sand has the largest particles, followed by silt, then clay. Texture can be determined by two methods: separation of size fractions in the lab, and by feel in the hand.

Texture by feel in the hand is determined by how well moist soil sticks together. Sandy soils have individual grains that feel gritty. If the soil holds its shape (known as a cast), it is loamy. If the cast can be rolled into thin ribbons between the fingers, that indicates clay.

Traditionally, clay soils were referred to as "heavy" because the soil stuck to the plow and made it heavy. By contrast, sandy soils were known as "light" soils because the sand grains did not stick to the plow.

## Soil Porosity

Soil is not a solid mass. The spaces between soil particles are called pores, and they allow water and air to move through the soil. Porosity is measured as the proportion of void space in a given volume of soil. Ideally, nearly half the volume of soil should be pore space.

Large pores allow internal drainage of water through soil and aeration for roots. Small pores are essential for retaining water for root absorption.

If soil is too dense, plants cannot absorb sufficient water and air. Insufficient pore space, therefore, may restrict root and plant growth or even lead to death. Further, roots cannot penetrate highly compacted soil where pore space has been removed.

## Soil Drainage

The position of soil in the landscape determines depth to the seasonal water table. Wet soils (very poor, poor, and somewhat poorly drained) will have a high water table for some portion of the growing season. Root growth may be restricted due to excessive moisture and limited aeration for respiration. On the other hand, drier soils (moderately well, well, and excessively drained) have a deeper water table. As drainage improves on drier sites, moisture may become limited during the growing season.

## Soil pH

Soil pH is a measure of acidity or alkalinity, which is the concentration of hydronium ions in the soil solution on a negative logarithmic scale. A soil pH of 7 is neutral, a pH value less than 7 is acidic, and a pH value greater than 7 is alkaline (also known as basic). Soil pH influences nutrient uptake and tree growth.

Many soil nutrients change chemical form as a result of reactions in the soil that are largely controlled by pH. Soils with a pH between 6.0 and 7.0 generally have the best growing conditions with regard to soil chemistry. At these pH levels, most nutrients are readily available. Nevertheless, the vast majority of commercially important tree species can live in a broad range of soil pH values as long as the proper balance of required nutrients is maintained.

Soil pH values at the extremes (less than 4.0 or greater than 8.5) can make some nutrients toxic and others unavailable to plants. At lower pH levels (less than 4.5), aluminum, iron, and manganese are very available for plant uptake, while at high pH levels (greater than 8.5), calcium and potassium are overabundant. In these situations, many plants will absorb too much of some nutrients and not enough of others. This situation may lead to physiological dysfunction within plants.

# Major Soil Resource Areas

In Mississippi, there are several major soil resource areas (Figure 2). These predominant soils and composite vegetation define major ecoregions across the state. These are the Delta, Loess Hills, Upper Coastal Plain, Blackland Prairie, Lower Coastal Plain, and Flatwoods.

## Delta

The Delta region of western Mississippi is part of the Mississippi River floodplain. Soils here are moist to wet, with medium to heavy texture. Historically, this region was covered by bottomland forests of cypress and oak. Clearing for agriculture began in the mid-1800s. Most of this area is in agricultural production, with a small proportion of land in bottomland hardwoods and pasture. Soybeans, cotton, wheat, and rice are the main crops.

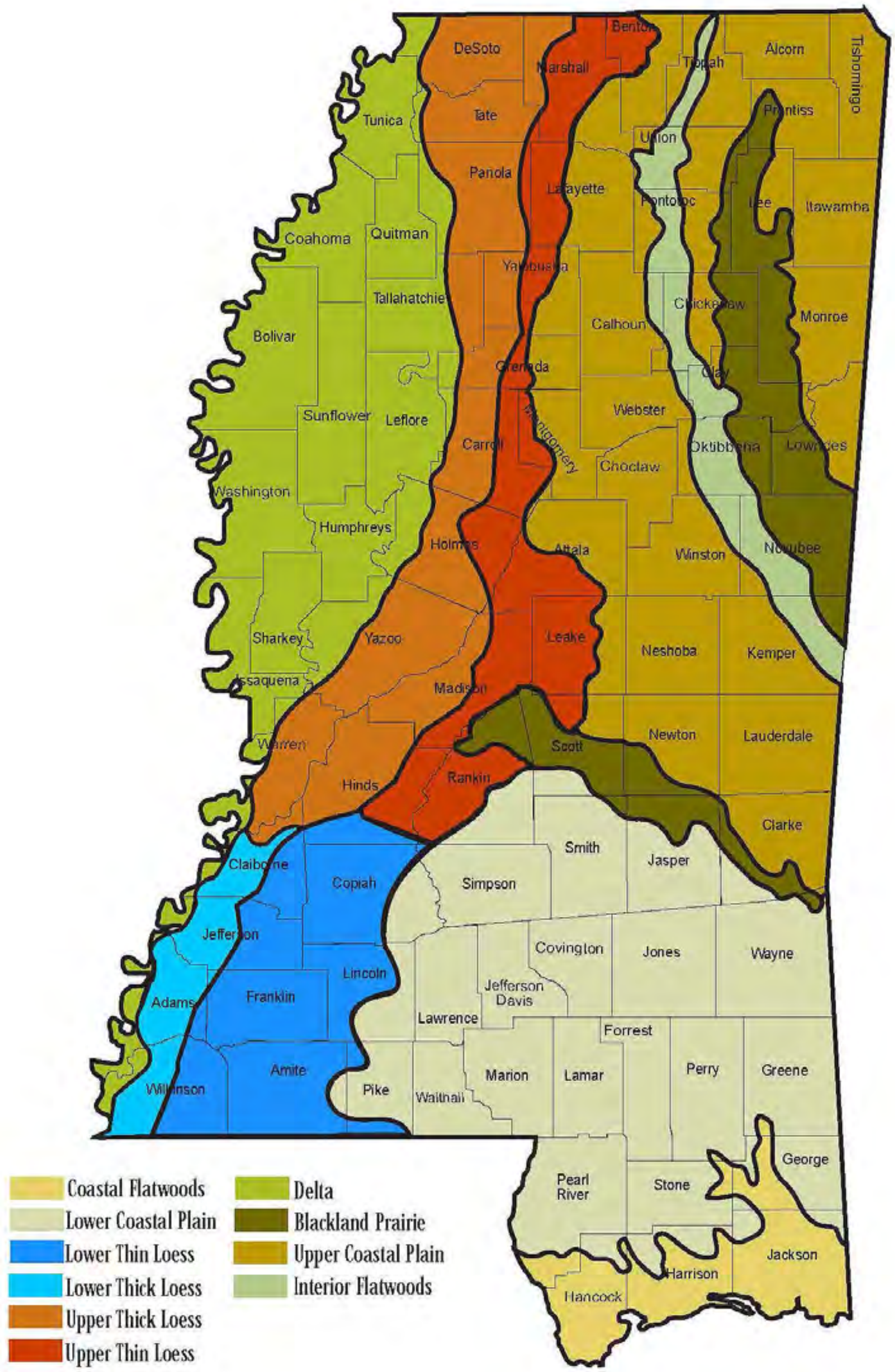



Figure 2. Major soil regions of Mississippi.

### Loess Hills

Adjacent to the Delta to the east are the Loess Hills, formed from wind-blown glacial outwash some 10,000 to 12,000 years ago. These silty upland soils are deep, well drained, and fertile. Forest production predominates, although agricultural production of cotton, corn, soybeans, and wheat is important.

### Upper Coastal Plain and Interior Flatwoods

The Upper Coastal Plain and Interior Flatwoods major soil regions are in the northeastern section of the state. The soils in these regions are older and more highly weathered, so they are less fertile than those to the west. These soils display advanced soil development, with well-defined topsoil and subsoil horizons. Mixed pine-oak forests predominate, with loblolly and shortleaf pines and a variety of upland and bottomland oaks. Major crops include soybeans, corn, peanuts, and vegetables. Pastures are a minor crop.

### Blackland Prairie

Interspersed within the Coastal Plains is the Blackland Prairie ecoregion. The Prairie soils bisect the northern and central portions of the state. Having developed from more chalky sediments, soils in this region are fine-textured with shrink-swell clays. Soil pH tends toward alkalinity. While forestry is significant, there is a greater amount of pasture and cropland in this region.

### Lower Coastal Plain and Coastal Flatwoods

In the southeastern corner of the state are the Lower Coastal Plain and the Coastal Flatwoods along the Gulf of Mexico. Predominant soils are sandy and wet with low native fertility. Forests cover nearly 90 percent of the area. The proximity of the coast caused natural vegetation here—including longleaf pine, slash pine, and live oak forests—to adapt to tropical storms and saline soils.

## Soil Management

Proper soil management requires a long-term commitment by landowners to sustain key soil properties. They must:

- protect the soil from erosion.
- maintain good physical condition of the soil.
- maintain proper balance of soil chemistry.
- maintain and enhance the organic components of the soil.

Management techniques will vary widely depending on land use, soil region, specific location, and topography of a given property.

Landowners are strongly encouraged to obtain a detailed soil map of their property from the Natural Resources Conservation Service (NRCS). These maps are available in the local NRCS office or online at **https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm**. The manuals and maps on the website provide a great deal of useful information, including drainage, fertility, best tree species to plant or manage, and development ratings.

The Mississippi State University Extension Service soil testing laboratory can determine site-level soil properties for a modest fee. Forms and soil sample boxes are available at the local **county Extension office**.

Routine soil testing through MSU Extension includes soil pH, liming requirements, and the amounts of available nutrients. If you specify a crop, fertilizer recommendations will also be included. Many helpful publications on interpreting soil test results for timber, horticulture, agriculture, and wildlife food plots are available at **https://extension.msstate.edu/publications**.

When conducting forest operations on your property, such as harvesting or spraying herbicides, it is important to specify the use of Mississippi best management practices (BMPs) in the contract. These guidelines are designed to help prevent soil erosion on roads and sedimentation in streams. These guidelines are voluntary in Mississippi but are enforceable when included in a contract.

**NCF-Envirothon 2026 Mississippi**

## Soils and Land Use Study Resources

**Key Topic #4: Soils, Land Use, and Society**

14. Describe common agricultural/urban practices and their effects on soil health.
15. Explain Land Capability Classification and analyze how certain types of soil are better suited than others for specific human uses (mining, farming, septic tanks, et cetera).
16. Explain the importance of the 1930's Dust Bowl on the Soil Conservation Movement.

| Resource Title | Source | Located on Page |
|---|---|---|
| Land Capability Classification (LCC) system | *Mississippi Soils Study Guide for the Mississippi Envirothon** | 93 |
| Land Capability Classes and How To Guide, Part III | *USDA-Natural Resources Conservation Service & Wisconsin Association of Agricultural Educators (WAAE). (2015). Soil Study and Land Evaluation Handbook: Wisconsin. USDA-Natural Resources Conservation Service.* *https://www.nrcs.usda.gov/sites/default/files/2022-11/Land_Judging_Handbook.pdf* | 95 |
| Principles for High Functioning Soils | *Soil Health Fact Sheets. (2018). USDA, Natural Resources Conservation Service.* *https://www.nrcs.usda.gov/sites/default/files/2022-12/NRCS-Principles-for-High-Functioning-Soils-Factsheet-2021-English.pdf* | 100 |
| The Dust Bowl: A wake-up call in environmental practices | *https://www.aaas.org/membership/scientia/dust-bowl-wake-callenvironmental-practices* | 103 |

# Land Capability Classification (LCC) System

The **Land Capability Classification (LCC) system**, developed by the USDA Natural Resources Conservation Service (NRCS), categorizes land into eight classes based on its suitability for cultivation and risk of erosion or soil damage.

**Land suitable for cultivation and other uses:**

**Class I** - Soils that have few limitations restricting their use. Lowest Management Risk

**Class II** - Soils that have some limitations, reducing the choice of plants or requiring moderate conservation practices.

**Class III** - Soils that have severe limitations that reduce the choice of plants or require special conservation practices, or both.

**Class IV** - Soils that have very severe limitations that restrict the choice of plants, require very careful management or both.

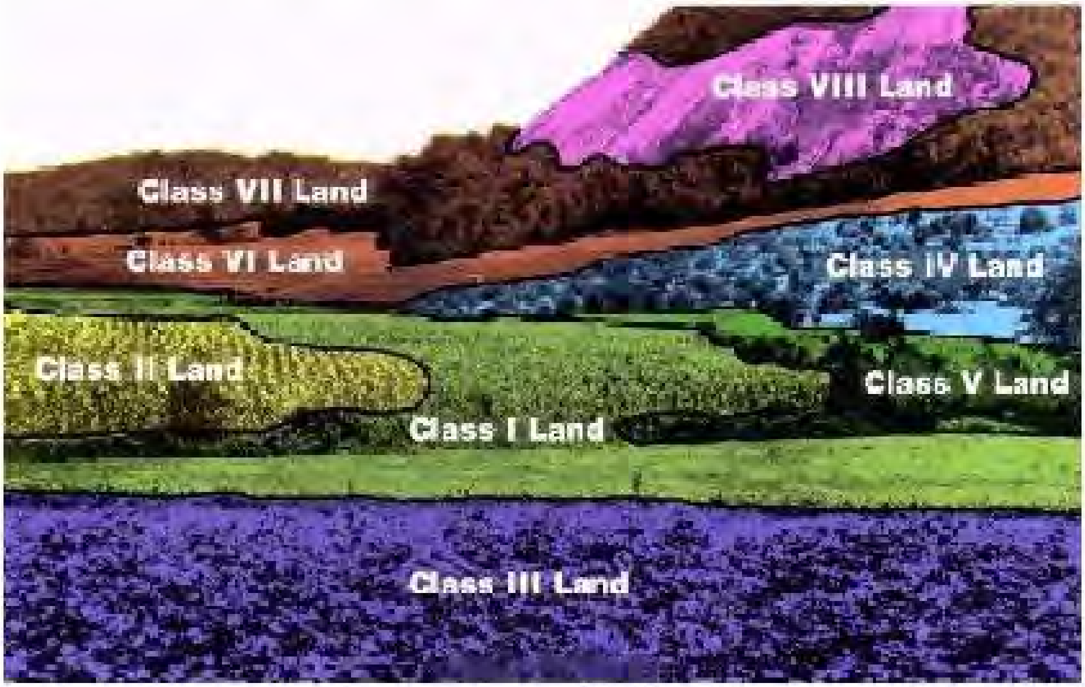
**Land generally NOT suitable for cultivation (without major treatment).**

**Class V** - Soils that have little or no erosion hazard, but that have other limitations, impractical to remove, that limit their use largely to pasture, range, woodland, or wildlife food and cover.

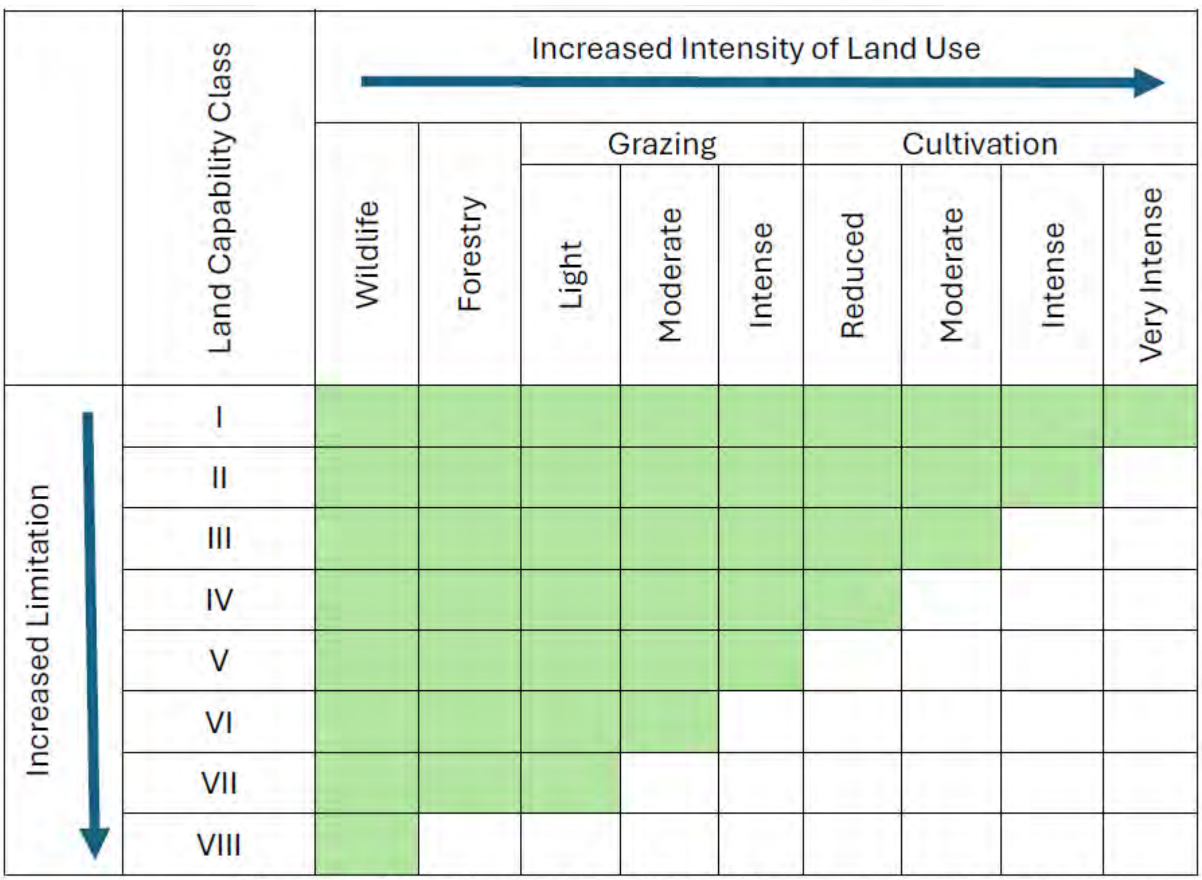
**Class VI** - Soils that have severe limitations that make them generally unsuited for cultivation and limit their use largely to pasture or range, woodland, or wildlife food and cover.

**Class VII** - Soils that have very severe limitations that make them unsuited to cultivation and that restricts their use largely to grazing, woodland, or wildlife.

**Class VIII** - Soils and landforms that preclude their use for commercial plant production and restrict their use to recreation, wildlife, water supply, or aesthetic purposes. Highest Management Risk




Landscapes with land capability classes outlined.




Green shading indicates LCC suitable with respect to particular Land Uses

# Part III

## Land Capability Classes

Land capability classification is a widely used system to classify soils for agricultural purposes. The system is based on the most intensive long term use for this land. The criteria used to classify Land Capability are: slope, texture of soil, depth of soil material, and drainage.

In this classification system, soils are grouped according to their potentials and limitations, if any, for sustained production of common crops. This classification system places all soils in eight capability classes. The higher the number, from Class I-VIII, the greater the risk of soil damage or limitations for use. With good soil conservation management, soils in Classes I, II, III, and IV, are suitable for cultivation. Soils in Classes VI and VII, with good soil conservation management, are suited for pasture, woodland and wildlife. Soils in Class VIII generally are non-productive for agricultural purposes and are recommended for wildlife habitat.

## Land Suited for Cultivation

**Class I**

May be safely used for intensive production such as continous row crops, pasture, woodland, or wildlife habitat. These soils are nearly level and the erosion hazard is slight. They are deep, generally well-drained, and easily worked. They hold water well and are naturally fertile or responsive to additions of fertilizer. They are not subject to damaging overflow.

# Land Suited for Cultivation (continued)

**Class II**

Requires general soil conservation systems which may require special tillage methods. Soils in this class have slight limitations and conservation practices are easy to apply. These soils may be used for crops, pasture, woodland or wildlife habitat. The soils have one or more limitations: slight hazard of wind or water erosion; occasional damaging overflow; moderate soil depth; wetness; or gentle slopes.

**Class III**

Requires specific practices and conservation measures. Soils in this class have moderate limitations and conservation practices are usually more difficult to apply and maintain. These soils may be used for cultivated crops, pasture, range, woodland or wildlife habitat. The soils have one or more limitations: moderate hazard of wind or water erosion; wetness; moderately shallow rooting depth; moderately low moisture holding capacity; or moderate slopes.

**Class IV**

Requires intensive soil conservation systems and practices. Soils in this class have severe limitations and conservation practices are more difficult to apply and maintain. These soils may be used for cultivated crops, pasture, woodland or wildlife habitat. The soils have one or more of the limitations: severe hazard of wind or water erosion; wetness; shallow rooting depth; low moisture holding capacity; or steep slopes.

# Land Generally Not Suitable For Cultivation

**Class V**

*Not used in Wisconsin*

**Class VI**

Generally ill-suited for cropland. Can be cropped with specific conservation and agronomic pracices (i.e. drainage, stone removal, etc.) Recommend permanent pasture, woodland or wildlife habitat. Use conservation practices for all land uses. These soils have one or more limitations: severe wind or water erosion; are stony, have shallow rooting depth, excessive wetness, low moisture capacity or steep slopes.

**Class VII**

Use very carefully for pasture. Improve for woodland or wildlife habitat. Needs careful conservation. Soils in this class have severe limitations that restrict their use to pasture, woodland or wildlife habitat. The soils are stony or sandy on moderate slopes, or any soil on very steep slopes (>30%). With proper management these soils can be used for limited pasture, woodland and wildlife production but it is seldom practical to apply pasture improvements such as seeding and fertilizing.

**Class VIII**

Reserve for wildlife production. Soils in this class have limitations that preclude their use for agricultural or commercial plant production. Limitations that cannot be overcome consist of one or more of the following: erosion or erosion hazard; stones; or very low moisture capacity. Class VIII is reserved for non-soil areas.

# How to Identify Land Capability Classes

The land capability classification system organizes land facts into groups to show the broad limitations, risks and intensity of use for lands having specific soil characteristics. The charts below show how soil characteristics determine land capability classes.

NOTE: For soils that have Severe Erosion, move one class poorer. Example, a Class III with severe erosion moves into Class IV. However, do not move from Class VII to Class VIII.

**START HERE**

**1.** For non-soil areas, like river wash, quarries, dumps, etc,

Capability Class = VIII. If not, go to 2.

**2.** For soils that are stony: (see definition for stoniness-Part II),

0-20 % Slope = Class VI
>20% Slope = Class VII If not go to 3

**3.** For soils that have a water table within 36 inches of the surface:

Use this table: If not go to 4

| Natural Profile Drainage (inches) | Percent Slope | Dominant Soil Texture | Capability Class | Capability Class if cropped and drained |
|---|---|---|---|---|
| Somewhat Poorly (water table 12-36) | <6 | loamy | II | |
| | 6-12 | loamy | III | |
| | <6 | clayey | III | |
| | <6 | sandy | IV | |
| Poorly (water table 0-12) | <6 | loamy | VI | II |
| | | clayey | VI | III |
| | | sandy | VI | IV |
| Very Poorly (organic 16-51" thick) | <6 | organic/loam | VI | II |
| | | organic/clay | VI | III |
| | | organic/sand | VI | IV |
| (organic >51" thick) | | organic | VI | III |

## 4.

For soils that have a dominant texture of sand or loamy sand (sandy soils) use this table. If not go to 5

| Percent Slope | Dominant Soil Texture | Capability Class |
|---|---|---|
| 0-6 | sand or loamy sand | IV |
| 6-12 | sand or loamy sand | VI |
| >12 | sand or loamy sand | VII |

## 5.

For all other soils use this table. Pick the correct slope range, then the correct soil texture. Then the correct soil depth, if needed.

| Percent Slope | Dominant Soil Texture in Profile | Depth of Soil | Capability Class |
|---|---|---|---|
| 0-2 | all textures but sandy loam | **>40 inches** | I-no overflow |
| 0-2 | all textures but sandy loam | >40 inches | II-occ. overflow |
| 0-2 | all textures but sandy loam | 20-40 inches | II |
| 0-2 | all textures but sandy loam | <20 inches | III |
| 0-2 | sandy loam | | III |
| 2-6 | all textures but sandy loam | **>20 inches** | II |
| 2-6 | all textures but sandy loam | <20 inches | III |
| 2-6 | sandy loam | | III |
| 6-12 | all textures | **>20 inches** | III |
| 6-12 | all textures but sandy loam | <20 inches | IV |
| 6-12 | sandy loam | <20 inches | VI |
| 12-20 | all textures | **>20 inches** | IV |
| 12-20 | all textures | <20 inches | VI |
| 20-30 | all textures | **>20 inches** | VI |
| 20-30 | all textures | <20 inches | VII |
| >30 | all textures | | VII |

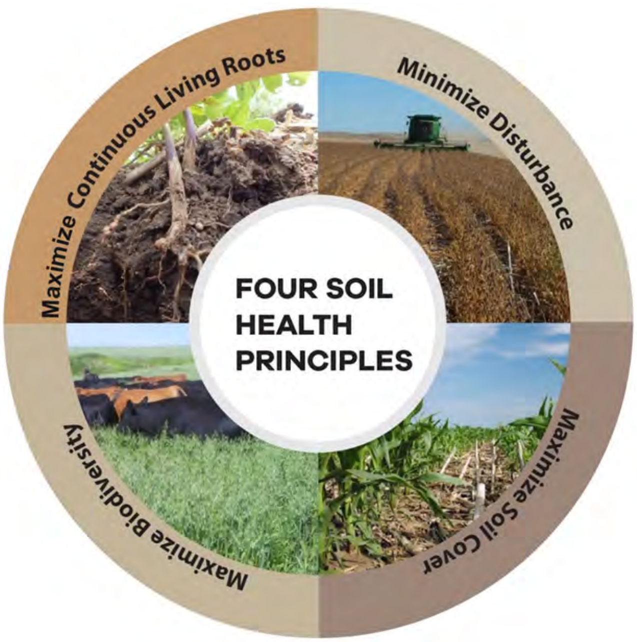
**How to Determine Dominant Soil Texture**
The marked profile will be a maximum of 40 inches. The ***Dominant Soil Texture*** will comprise at least half of the marked profile.

unlock the SECRETS IN THE SOIL

# PRINCIPLES FOR HIGH FUNCTIONING SOILS

## SOIL HEALTH DEFINED

Soil health is **the continued capacity of a soil to function as a vital, living ecosystem that sustains plants, animals, and humans**. Only living things can have "health," so viewing soil as a living, breathing ecosystem reflects a shift in the way we view and manage our nation's soils. Soil isn't an inert growing medium, but rather is the home of billions of bacteria, fungi, and other organisms that together create an intricate symbiotic ecosystem. This ecosystem can be managed to support plants and animals, by cycling nutrients, absorbing, draining and retaining rainwater and snowmelt for use during dry periods, filtering and buffering water to remove potential pollutants, and providing habitat for the soil biological population to flourish and diversify to keep the ecosystem functioning well.




## KEY SOIL HEALTH MANAGEMENT PRINCIPLES

These principles are represented in the circular diagram to the right to emphasize their relationship as a continuum where each complements the others and also depends on the others.

1. Minimize disturbance
2. Maximize soil cover
3. Maximize biodiversity
4. Maximize presence of living roots

## PROTECTING THE SOIL HABITAT

The first two principles, shown on the right side of the diagram above focus on protection of the soil habitat: minimize disturbance and maximize soil cover. Practices that use these principles maintain or increase stable soil aggregates and soil organic matter (SOM), and protect the surface of the soil that is most susceptible to the degrading forces of wind and water. Maximizing soil cover also buffers against temperature fluctuations that stress plants and soil organisms, reduces evaporation rates, and increases the amount of water entering the soil profile from precipitation and irrigation.

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SOM is highest at the soil surface and is critical for stabilizing soil aggregates.

Maintaining SOM helps support additional soil functions including water infiltration, drainage and storage, nutrient-holding capacity and release, and habitat for soil biota.

## FEEDING THE SOIL ORGANISMS INHABITING SOIL

The second two principles, shown on the left side of the circular diagram, focus on feeding soil organisms. Maximizing the diversity of food (energy and carbon inputs) and aboveground biodiversity increases the diversity of soil animals and microorganisms. Diversity not only refers to food sources, but also aboveground diversification of plants and animals, and microbial diversification underground. Diversification stimulates a host of additional benefits including breaking disease cycles, providing habitat for pollinators, and stimulating plant growth.

Maximizing the presence of living roots in the soil can be accomplished through eliminating fallow, diverse crop rotation, inclusion of cover crops, and/or through dedicated grasslands (native or pasture). Mixing up which plants are grown during the year or over the course of multiple years may help to break disease/pest cycles.

When these two principles are properly applied as part of a soil health management system, soils can maintain or even increase SOM content as well as enhance nutrient cycling.

*Worm being born within the pore space of a well-aggregated soil.*

## HEALTHY, FUNCTIONING SOILS ARE ABLE TO:

- Cycle nutrients effectively
- Store carbon and nutrients in soil organic matter
- Provide good aeration to promote root growth
- Improve farm and ranch resiliency and profitability
- Improve yield stability
- Reduce runoff and erosion
- Improve water storage and plant available water while protecting water quality
- Be resilient to drought, heavy rainfall events, and temperature extremes
- Reduce disease and pest problems

**Soil Health Management Systems Principles can be generally used in all production systems to achieve this. However, the specific practices chosen to implement the principles must be adapted to each production system, climate, ecosystem, and soil to effectively build and maintain healthy, functioning soil.**

### SOIL DISTURBANCES

Physical disturbances such as tillage or compaction from heavy machinery; Chemical disturbances such as fertilizer and pesticide applications, especially over application or misuse. Biological disturbances, such as over-grazing animals that can lead to compaction and reduction in perennial root systems, introduction of invasive species and/or use of monocultures can cause biological imbalances which all can affect soil functions.

### SOIL COVER

consists of two main forms: 1) living plant canopy such as a growing crop, cover crop, or grassland; and 2) mulch, either as dead plant material (e.g. crop residues, prunings from trees and shrubs, thatch in grasslands) or as an amendment (e.g. compost, bark chips).

### BIODIVERSITY

is the variation of life forms within a given ecosystem or field. The different life forms include all of the plants, animals and microorganisms, and their secretions. For soil health management systems, biodiversity can be increased through a variety of approaches including: plant diversity through the use of diversified crop rotations, cover crop mixes, diversity through the proper integration of grazing animals (e.g. livestock) into the system and includes animals living within the soils or microbial diversity, as well as direct additions with biological amendments. All four soil health management principles contribute to biodiversity.

# Soil Health Management Systems Include:

| What is it? | | What does it do? | How does it help? |
|---|---|---|---|
| **Conservation Crop Rotation**<br>Growing a diverse number of crops in a planned sequence to increase soil organic matter and biodiversity in the soil. |  | • Increases nutrient cycling<br>• Manages plant pests (weeds, insects, and diseases)<br>• Reduces sheet, rill and wind erosion<br>• Holds soil moisture<br>• Adds diversity so soil microbes can thrive | • Improves nutrient use efficiency<br>• Decreases use of pesticides<br>• Improves water quality<br>• Conserves water<br>• Improves plant production |
| **Cover Crop**<br>An un-harvested crop grown as part of planned rotation to provide conservation benefits to the soil. |  | • Increases soil organic matter<br>• Prevents soil erosion<br>• Conserves soil moisture<br>• Increases nutrient cycling<br>• Provides nitrogen for plant use<br>• Suppresses weeds<br>• Reduces compaction | • Improves crop production<br>• Improves water quality<br>• Conserves water<br>• Improves nutrient use efficiency<br>• Decreases use of pesticides<br>• Improves water efficiency to crops |
| **No Till**<br>A way of growing crops without disturbing the soil through tillage. |  | • Improves water holding capacity of soil<br>• Increases organic matter<br>• Reduces soil erosion<br>• Reduces energy use<br>• Decreases compaction | • Improves water efficiency<br>• Conserves water<br>• Improves crop production<br>• Improves water quality<br>• Saves renewable resources<br>• Improves air quality<br>• Increases productivity |
| **Mulch Tillage**<br>Using tillage methods where the soil surface is disturbed but maintains a high level of crop residue on the surface. |  | • Reduces soil erosion from wind and rain<br>• Increases soil moisture for plants<br>• Reduces energy use<br>• Increases soil organic matter | • Improves water quality<br>• Conserves water<br>• Saves renewable resources<br>• Improves air quality<br>• Improves crop production |
| **Mulching**<br>Applying plant residues or other suitable materials to the soil surface to compensate for loss of residue due to excessive tillage. |  | • Reduces erosion from wind and rain<br>• Moderates soil temperatures<br>• Increases soil organic matter<br>• Controls weeds<br>• Conserves soil moisture<br>• Reduces dust | • Improves water quality<br>• Improves plant productivity<br>• Increases crop production<br>• Reduces pesticide usage<br>• Conserves water<br>• Improves air quality |
| **Nutrient Management**<br>Managing soil nutrients to meet crop needs while minimizing the impact on the environment and the soil. |  | • Increases plant nutrient uptake<br>• Improves the physical, chemical and biological properties of the soil<br>• Budgets, supplies, and conserves nutrients for plant production<br>• Reduces odors and nitrogen emissions | • Improves water quality<br>• Improves plant production<br>• Improves air quality |
| **Pest Management**<br>Managing pests by following an ecological approach that promotes the growth of healthy plants with strong defenses, while increasing stress on pests and enhancing the habitat for beneficial organisms. |  | • Reduces pesticide risks to water quality<br>• Reduces threat of chemicals entering the air<br>• Decreases pesticide risk to pollinators and other beneficial organisms<br>• Increases soil organic matter | • Improves water quality<br>• Improves air quality<br>• Increases plant pollination<br>• Increases plant productivity |

USDA United States Department of Agriculture

# The Dust Bowl: A wake-up call in environmental practices

## 3 December 2012

**by: Susan Borowski**

A dust storm approaches Stratford Texas on April 18, 1935, four days after Black Sunday. (Image: NOAA George E. Marsh Album)

Ken Burns' latest historical documentary **"The Dust Bowl"** reminds us of a somewhat-forgotten era when poor policies and farming practices helped create the worst environmental disaster in U.S. history. One cannot help but notice the similarities between the impact of environmental policies and practices then, which affected a huge region of the United States, and those of today, which affect the entire planet.

In the 1930s, the farmers, the economy, and the government policies of the time all played a part in wreaking havoc on the Great Plains, the "breadbasket" of America. Plowing practices combined with a decade-long drought produced wind erosion the like of which the U.S. had never seen. Once-fertile grassland was turned into a literal desert. Huge sand and dust storms swept all the way to the East Coast, even dusting the halls of Congress and the White House.

Worst were the "black blizzards," huge, rolling storms of black dust that engulfed everything in their path for hundreds of miles. The worst such blizzard occurred on Black Sunday, April 14, 1935, starting in the Plains and blowing east at 60 miles per hour, ending 200 miles out into the Atlantic.

The drought began in the summer of 1931. According to the National Weather Service, the number of regional dust storms increased from 14 in 1932 to a high of 72 in 1937; it wasn't until 1940 that they subsided, with a total of 17 that year. Although all Plains states were affected to some degree, the areas hardest hit were southeast Colorado, northeast New Mexico, southwestern Kansas, and the Oklahoma and Texas Panhandles.

What people didn't realize, or realized but ignored, was that the deep-rooted grassland that covered the Plains held the soil in place. That grassland was not only being plowed up to grow wheat, but overstocking of cattle also contributed to the destruction of grassland with overgrazing.

The farming practices of the time were particularly damaging. Between 1925 and 1930, plenty of rain and high demand for wheat, in addition to the use of more modern farming equipment such as gasoline tractors and harvester-combines, led to 33 million acres being completely denuded and vulnerable when the drought hit, allowing the soil to easily be swept away. Plowing was deep, which contributed to soil erosion. Cotton farmers left fields bare over the winter months, when the winds were at their highest, and burned the plant stubble to control weeds, which further removed any anchoring vegetation.

Because most farms were small family-run operations, there was a lack of coordination in conservation efforts, and most farmers resisted them. When the Great Depression hit in 1929 and wheat prices began to plummet, farmers responded by plowing even more land to make up for the loss in price per bushel.

Hugh Hammond Bennett, who came to be known as "the father of soil conservation," led a campaign to reform farming practices with the backing of President Roosevelt. Some of the new methods he introduced included crop rotation, strip farming, contour plowing, terracing, planting cover crops and leaving fallow fields (land that is plowed but not planted). Because of resistance, farmers were actually paid a dollar an acre by the government to practice one of the new farming methods. In addition, the Civilian Conservation Corps was ordered to plant 200 million trees from Canada to Texas to serve as a windbreak and help hold the soil in place.

By the end of the decade, the combination of new farming techniques and the return of the rain ended the era of the Dust Bowl, though the cost is unimaginable: to the people who left, to the people who stayed, to the environment, and to the economy.

After suffering the worst drought in over 50 years in 2012, it's clear that we have learned from the mistakes of the past. Although crop yields were down, higher prices and insurance helped to cover the economic loss, and farmland values have actually risen. But much of the High Plains remains in what is known as an "Exceptional Drought," level D4 according to the **U.S. Drought Monitor**. This is the highest level, and many areas surrounding this zone are still experiencing extreme and severe drought.

Today, we worry about the effect we have on the environment on a global scale. We worry that the emission of greenhouse gases, depletion of the ozone layer, and other effects of industrialization are wreaking havoc with the gradual warming of the atmosphere. In the 1930s, it took extensive government intervention to turn the tide. While there certainly has been some government intervention in fuel standards, emissions and in other areas in the U.S., as well as interventions in other countries, the tide doesn't appear to be turning.

One only needs to look at the Dust Bowl to realize that at some point, nature will fight back. After enduring unprecedented catastrophes in the U.S. in just the past few years, most recently Hurricane Sandy, one wonders if nature's fury has just begun.

## Soils and Land Use Study Resources

**Key Topic #5: Field Skills**

17. Identify characteristics of a soil pit or soil sample, including horizons, color, structure, texture, and special features.
    a. Horizons *(see pages 12- 13)*
    b. Color *(see pages 27-36)*
    *c.* Texture *(see pages 37–43 & 98-99)*
    d. Structure *(see pages 45-48)*
18. Drainage class and limitations on selected uses.
    a. Soil Drainage Classes *(see pages 31 & 56-58 & 86)*
19. Use a soil triangle to evaluate the texture of a soil. *(see pages 37–43 and 98-99)*
20. Interpret designations of the Land Capability class system. *(see Pages 90-91)*
21. Apply knowledge of Best Management Practices (BMPs) for soil health to determine which are best suited to specific soil and substrate types, climatic conditions, and land uses. *(see pages 92-94)*

| **Resource Title** | **Source** | **Located on Page** |
|---|---|---|
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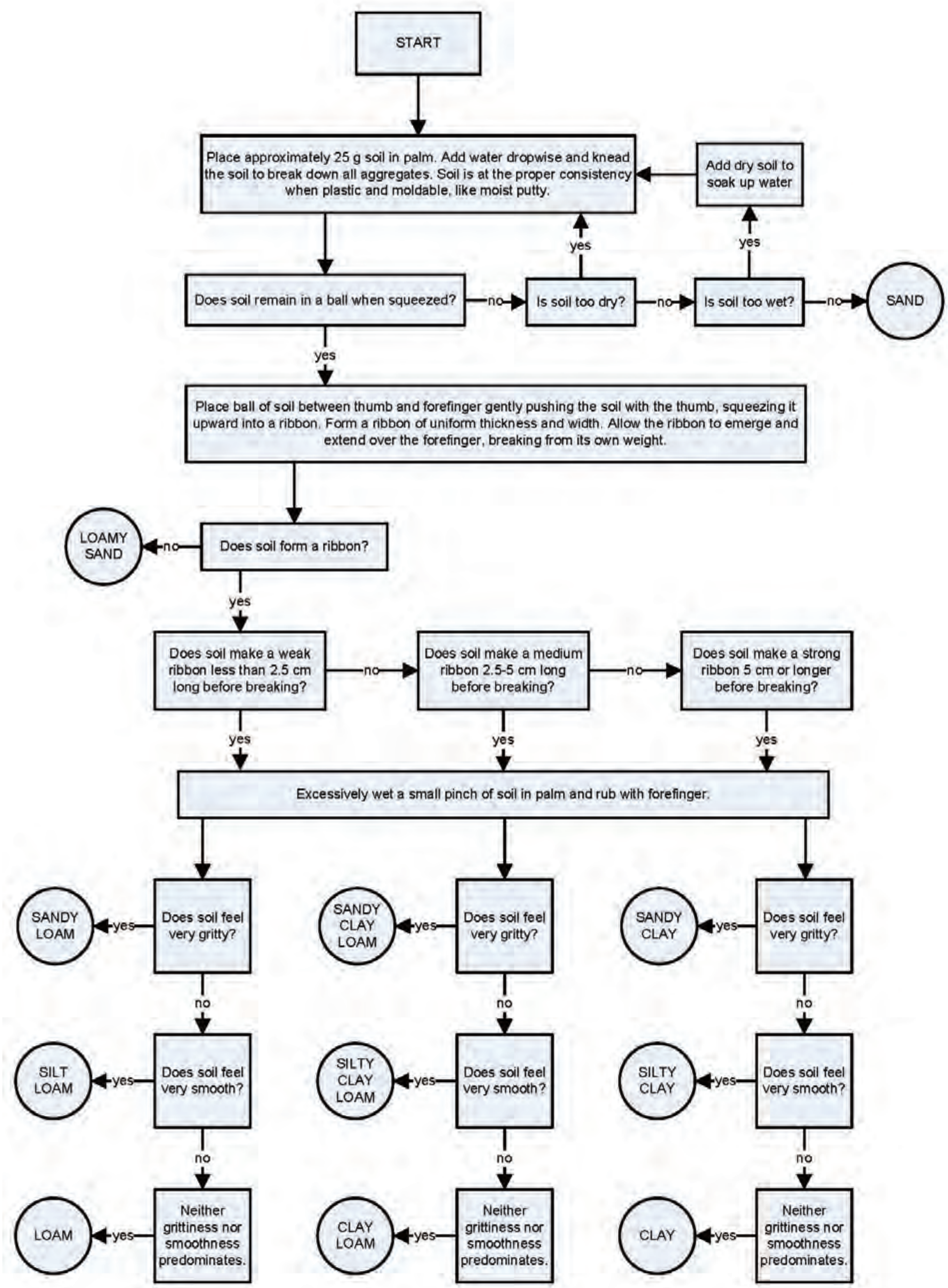
## Guide to Texture by Feel

Modified from S.J. Thien. 1979. *A flow diagram for teaching texture by feel analysis.* Journal of Agronomic Education. 8:54-55.




Texture class is one of the first things determined when a soil is examined. It is related to weathering and parent material. The differences in horizons may be due to the differences in texture of their respective parent materials.

Texture class can be determined fairly well in the field by feeling the sand particles and estimating silt and clay content by flexibility and stickiness. There is no field mechanical-analysis procedure that is as accurate as the fingers of an experienced scientist, especially if standard samples are available. A person must be familiar with the composition of the local soils. This is because certain characteristics of soils can create incorrect results if the person does not take these characteristics into account.

In some environments clay aggregates form that are so strongly cemented together that they feel like fine sand or silt. In humid climates iron oxide is the cement. In desert climates silica is the cement and in arid regions lime can be the cement. It takes prolonged rubbing to show that they are clays and not silt loams.

Some soils derived from granite contain grains that resemble mica but are softer. Rubbing breaks down these grains and reveals that they are clay. These grains resist dispersion and field and laboratory determinations may disagree.

Many soil conditions and components mentions earlier cause inconsistencies between field texture estimates and standard laboratory data. These are, but not limited to, the presence of cements, large clay crystals, and mineral grains. If field and laboratory determinations are inconsistent, one or more of these conditions is suspected.

### Soil Textural Triangle