# INTRODUCTION TO SOIL SCIENCE LABORATORY MANUAL (SCHWYTER AND VAUGHAN)

*Anna R. Schwyter & Karen L. Vaughan*
University of Wyoming

LibreTexts™

**Intro to Soil Science Laboratory Manual**

Anna R. Schwyter

University of Wyoming, aschwyte@uwyo.edu

Karen L. Vaughan

University of Wyoming, karen.vaughan@uwyo.edu

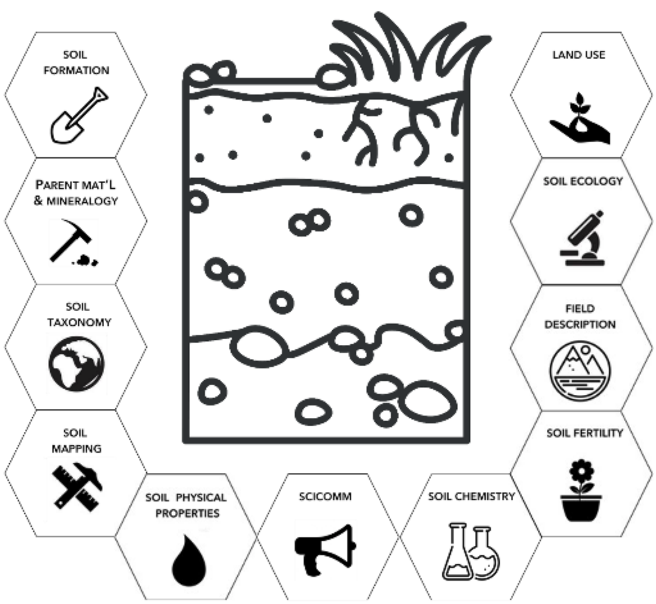


# Introduction to Soil Science Laboratory Manual

Anna R. Schwyter

Karen L. Vaughan

2020



The LibreTexts libraries are Powered by NICE CXone Expert and was supported by the Department of Education Open Textbook Pilot Project, the California Education Learning Lab, the UC Davis Office of the Provost, the UC Davis Library, the California State University Affordable Learning Solutions Program, and Merlot. This material is based upon work supported by the National Science Foundation under Grant No. 1246120, 1525057, and 1413739.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation nor the US Department of Education.

Have questions or comments? For information about adoptions or adaptions contact info@LibreTexts.org or visit our main website at https://LibreTexts.org.

This text was compiled on 03/19/2026

# TABLE OF CONTENTS

# Licensing

*A detailed breakdown of this resource's licensing can be found in* ***Back Matter/Detailed Licensing****.*

# CHAPTER OVERVIEW

## 1: Introduction to Soil Science and Soil Formation

Learning Objectives

- To recognize the variety of sub-disciplines that exist within soil science
- To define “soil”
- To understand the primary soil forming factors and processes
- To learn the concepts and methods used for identifying and describing soils (color, structure, texture)

**GOAL**: To better understand the concepts of soil formation and applications of methods for describing and identifying soils



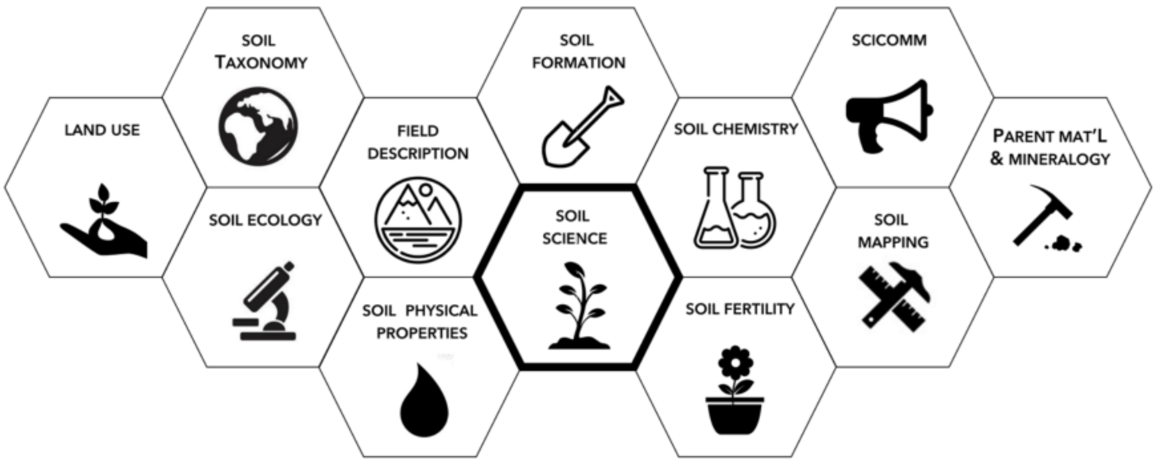
**Additional resources**:

- Video link: Soils Sustains Life: https://youtu.be/vDL6F6GkAzI (length: 2:54)
- Video link: The Science of Soil: Why Study Soil? https://youtu.be/og3TUc9xQaE (length: 4:19)

# 1.1: Introduction

Soil is the medium for plant growth at the land surface. Most of the world's food supply comes from plants growing in the soil (oceans and lakes supply some food). Soil serves as the habitat for thousands of species of animals, insects, and microorganisms. Soils support buildings, highways and other structures. Soils capture rainwater and melting snow to recharge our precious ground water. Soils also adsorb air and water pollutants. Soil microorganisms constitute the major component of life in the earth and cause many major biochemical transformations essential to our lives.

Throughout the duration of this course you wil dive deeper into the concepts and understandings of each of the following sub-disciplines, or focal areas of interest, within the discipline of soil science:




By nature of these sub-disciplines, soil science is inherently an interdisciplinary field. For this first lab, we will begin to learn a bit more about this interdisciplinary science by understanding the fundamentals of soil formation, soil characteristics, and the methods used for identifying and describing soils.

## SOIL FORMATION

Soil is defined as: "a natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the fol owing: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment" (Keys to Soil Taxonomy, 2012).

Soils exist in three dimensions (**pedon**; 3 dimensional bodies) containing inorganic and organic material generally arranged into layers from the land surface downward into the earth. These layers of topsoil and subsoil (being roughly parallel to the ground surface) are called **horizons**. A two-dimensional vertical section of soil extending through these horizons downward to the parent material is called a **profile**.

Soils form in place based on five natural **soil forming factors**, including: 1) Climate; 2) Organisms; 3) Relief; 4) Parent Materials; And, 5) Time (Figure 1). Collectively, these five factors contribute to the function of soil formation (S), S= f (**Cl, O, R, P, T**…), otherwise known as **pedogenesis**. As the diagram suggests, soil formation is a continuum. As any one factor or influence changes, the final soil product will vary. An infinite number of combinations of soil forming processes yield many different soil properties.

Understanding the role of each soil forming factor allows us to understand or predict soil occurrence.

These five soil forming factors also work through four important **soil forming processes** (Table 2), considered in the following four groups: 1) Additions; 2) Losses; 3) Transformations; And, 4) Translocations.

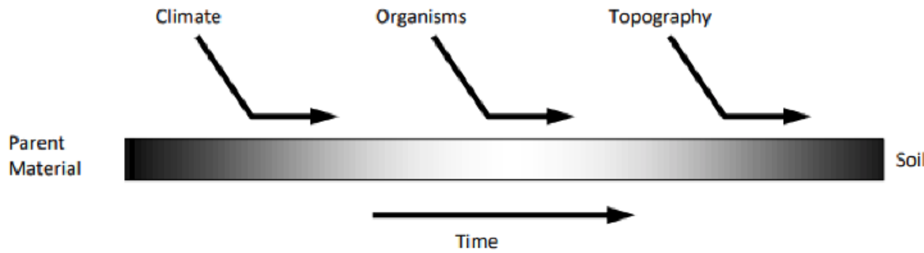



Figure 1. "The soil forming factor continuum" by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

Table 1. Examples of soil forming factors

| Soil Forming Factor | Example |
|---|---|
| Climate | Temperature, precipitation, evaporation |
| Organisms | Vegetation, fauna, human influence |
| Relief | Slope, erosion/sedimentation, hillslope position |
| Parent Material | Mineralogy, bedrock, chemical species present, texture |
| Time | Change of boundary conditions |

Table 2. Examples of soil forming processes

| Soil Forming Process | Example |
|---|---|
| Additions | Organic matter, fertilizers, dust deposition, other mineral soil |
| Losses | Movement of soil via wind or water, OR chemical compounds leached, eroded, or harvested from the soil |
| Transformations | Chemical or physical weathering of soil particles or components |
| Translocations | Movement of soil components (organic or mineral) between horizons within a soil profile |

While these factors and processes contribute to the natural formation of soil, it is also acknowledged that soil formation is likewise impacted by what is referred to as, "the human factor". As such, we all play a part in the formation, conservation, and protection of soil. As we manipulate the earth's surface, we can either improve or degrade our quality of lives. Regardless of the effect, we become responsible for the stewardship of our land – and good land stewardship requires us to understand the properties and processes of soils.

## SOIL MORPHOLOGY, PROPERTIES, and IDENTIFICATION

Soils form from parent materials, which are acted upon by the four basic soil forming processes aforementioned. These four processes aid in distinguishing soils from layers of materials deposited by geologic processes. The extent to which these four basic processes occur help differentiate soils.

### Soil Horizons

The horizon is different from the layers above and below it in the same soil. In total, there are five major soil horizons, called master soil horizons, which are distinguishable by their color, composition, and other characteristics.

#### *O horizon*

An O horizon consists of organic material deposited on top of the mineral surface. Often, various stages of decomposition can be recognized, with fresh material at the surface and decayed material below.

Most soils do not have an O horizon or, at best, they have only a thin O horizon either because soil microorganisms rapidly decompose the organic material, or very little organic material is deposited on the soil surface due to a lack of vegetative growth.

However, some forest soils may have an appreciable accumulation of organic matter as an O horizon. This may consist of broadleaf litter or more commonly as a thick layer of pine needles.

### *A horizon*

The A horizon is the mineral horizon characterized by a dark color caused by an accumulation of organic matter (humus) mixed into the mineral soil. A horizons usually have high biological activity. A horizons can be leached of clay, but remain dark because of organic matter replenishment. Most soils have an A horizon. A few soils may lack an A horizon either because they are very young or they have been severely eroded.

### *E horizon*

The E horizon is light in color compared to the A horizon above or B horizon below. The E horizon is the zone of maximum eluviation. Eluviation is the slow removal of fine clay and organic material by water percolating down through the soil. The E horizon is usually found in sandy soils receiving high rainfall under forest vegetation.

### *B horizon*

The B horizon is the mineral horizon usual y occurring beneath an A or an E horizon and above a C

horizon. The B horizon is the zone of maximum illuviation. Illuviation is the process of accumulation of clay, iron or aluminum oxides, humus, or some combination of these materials weathered in place or leached by eluviation from the overlying horizons. Some soils lack a B horizon because they are too young for materials to have had time to move downward by percolating water flow.

### *C horizon*

The C horizon is the layer of unconsolidated earth materials that exhibit the least evidence of physical disintegration, chemical decomposition and root development. The C horizon is weathered parent material from which the A, E, and B horizons can develop. The parent material for any horizon is the material from which that horizon developed.

### *R layer*

The R layer consists of the underlying hard bedrock material. Granite, basalt, sandstone, and limestone are common examples of R layer material. R layers are not considered soil.

### *Subdivisions/Subscripts*

In the field, the master soil horizons may be subdivided to note special soil features. Some of the most common features are the effects of plowing (Ap), the development of a new B horizon (Bw), water-logging (Bg or Cg), accumulation of carbonates (Bk) or clay (Bt), and soft rock parent material (Cr). An AB

symbol represents a horizon between the A and the B, which has some properties of each horizon.

## Soil color

Color is one of the most important physical characteristics of soil. It can be used to differentiate among various soil horizons (layers of soil), to estimate organic matter content, to evaluate the soil drainage class, and to assess many other soil conditions. The Munsell Color System, as approved by the National Bureau of Standards, is used to identify soil color. The Munsell Color System has been developed internationally to describe any color anywhere. It has nothing to do, directly, with soil.

In the Munsell Color System, three component parts describe the colors: **hue, value, and chroma** (always designated in exactly this order). Hue is the spectral variable. Hue represents one of the dominant colors of the rainbow, for example, yellow or red. Value represents the relative darkness or lightness of the color. Chroma represents the purity, strength, or saturation of a color. Colors having zero chroma are gray to black.

A Munsell Color Book is used to identify soil color. The book's pages display chips of various colors, which are matched as closely as possible to the soil color in the field. Each page represents a different Hue. Common pages used for soil studies include 10R, 5YR, 10YR, and 2.5Y hues. The letter R represents Red and the letter Y represents Yellow. Red soils are common when iron oxides are abundant in the soil profile. The pages go from 2.5R (pink) and 5R (yel owish pink), both of which are seldom used, to 7.5R (reddish orange) to 10R (dark reddish orange; commonly associated with iron oxides). The hues, which consist of increasing amounts of yellow mixed with red, are designated as 2.5YR (brownish orange), 5YR (strong brown), 7.5YR (moderate brown), and 10YR (medium brown). As the red is eliminated, more yellow is emphasized with 2.5Y (light olive brown) and 5Y (moderate olive). For a few strongly flooded soils, which have no free oxygen gas, the colors are very dark blue, dark greenish, dull bluish gray, or black.

On each page of the Munsell Color Book, the value is listed in increasing numerical order from the bottom to the top of the page (vertical y). The lower rows at the bottom of the page have low values and are dark colored. The upper rows at the top of the page have higher values and are lighter colored.

The columns of color going from left to right (horizontally) give the chroma. The left columns (low chroma) represent gray or pale colors. The right columns (high chroma) are more deeply or brightly colored. Thus, a single hue has many combinations of a value and a chroma.

The Munsel Color Notation consists of the color name folowed by the sequence, hue, value/chroma (i.e. 5 YR 3/2). A brown soil is designated by the notation 10YR 5/3. The name of the color is found on the page facing the color chart.

## Soil Texture

The solid portion of soils consists primarily of mineral particles (usually more than 95 % by mass) mixed with organic materials. These mineral particles are divided into coarse fragments greater than 2 mm in diameter (termed gravel), and finer particles less than 2 mm in diameter.

The fine particle fraction is further divided into arbitrary size classifications known as soil separates. The three soil separates are sand, silt, and clay. These three separates remain essentially constant during your lifetime in any given soil. The size classification of these soil separates is shown in Table 3.

Table 3. Size Classification of Soil Separates

| Particles | Diameter (mm) |
|---|---|
| Sand | 2.0 to 0.05 |
| Silt | 0.05 to 0.002 |
| Clay | less than 0.002 |

Soil texture is defined by the relative proportion of sand, silt, and clay. Soil texture remains constant for any given soil during your lifetime. Because texture is limited to sand, silt and clay, other soil components, including water, air, organic matter, and inorganic materials larger than 2 mm, are excluded, although gravels and cobbles may be included as modifiers to the textural name. Texture applies only to mineral soils. Organic soils such as peat and muck, do not have texture.

Percentage is determined by multiplying the decimal fraction of two numbers by 100 %. The symbol % means “per cent” which can be translated mathematical y to mean “per” = to divide by the number, and “cent” = 100. Thus % means “divide by 100" which is the same as to multiply by (1/100). Thus, to multiply by 100 % is the same as multiplying by 100 x (1/100) which equals 1.0. Therefore, multiplying any decimal fraction by 100% does not change the value of the original decimal fraction because it is the same as multiplying by 1.0. Note, it is incorrect to multiply only by 100. The correct form is to multiply by 100%, not by 100 alone.

The percentages of sand, silt and clay are calculated from laboratory data according to the following definitions:

$$\%\text{Sand} = \frac{\text{mass (g) of sand}}{\text{mass (g) of sand} + \text{silt} + \text{clay}} \times 100\%$$

$$\%\text{Silt} = \frac{\text{mass (g) of silt}}{\text{mass (g) of sand} + \text{silt} + \text{clay}} \times 100\%$$

$$\%\text{Clay} = \frac{\text{mass (g) of clay}}{\text{mass (g) of sand} + \text{silt} + \text{clay}} \times 100\%$$

Remember, percent (%) is defined as parts per hundred (pph).

Example: The following data were obtained about a soil sample:

mass of sand = 15.5 g

mass of silt = 17.0 g

mass of clay = 17.5 g

total mass of dry inorganic soil < 2 mm in diameter = 50.0 g

$\%Sand = \frac{15.5\ g\ sand}{50.0\ g\ dry\ soil} \times 100 = 31.0\%$ = 31.0 pph sand in soil

$\%Silt = \frac{17\ g\ silt}{50.0\ g\ dry\ soil} \times 100 = 34.0\%$ = 34.0 pph silt in soil

$\%Clay = \frac{17.5\ g\ clay}{50.0\ g\ dry\ soil} \times 100 = 35.0\%$ = 35.0 pph clay in soil

Soils having similar textures can be grouped into classes of soils having similar characteristics and behavior. Twelve soil textural classes are given in the textural triangle (Fig.2). The textural classes provide a way to express soil texture without referring specifically to the percentages of each separate.

When any two of the three percentages are known, the soil textural class can be determined from the triangle. This is why only two axes are required to plot the textural class for any given soil.

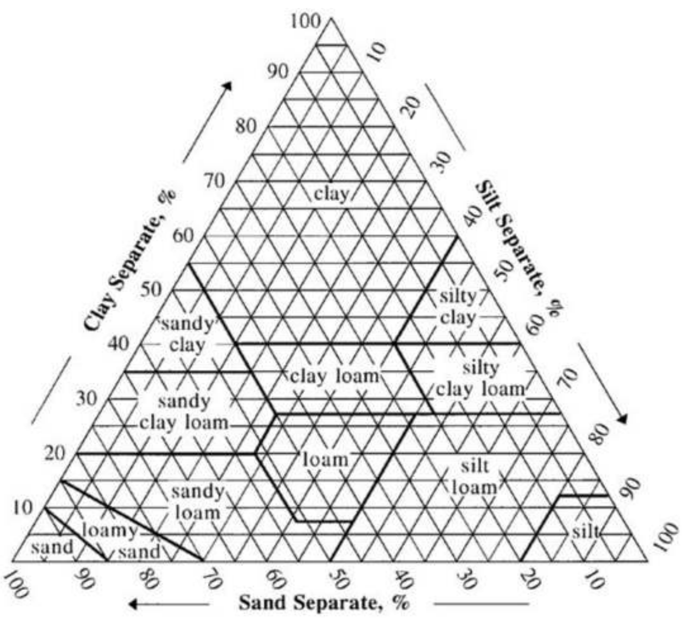



Figure 2. USDA Soil Survey Division Staff, SoilTextureTriangle, marked as public domain, more details on Wikimedia Commons

Locate the percent sand along the bottom (horizontal axis) of the triangle. Locate the percentage of clay along the left-hand axis of the triangle. Move upward from the sand percentage and to the right of the clay percentage until these two projected lines intersect. This point of intersection corresponds to the textural class corresponding to this particular portion designated on the triangle.

If a soil falls on the boarder of a texture (in-between textures), soil scientists have adopted the convention of adding 1% clay to the actual value and reporting the textural class name associated with this 1% clay addition. The reason for making this decision is based upon the fact the clay content is the most difficult to analyze of the three soil separates.

A soil's textural class may be determined by several methods that range from quick and simple field tests to more involved laboratory techniques. The "field" or “feel" method is the simplest to conduct, but it is the least accurate due to differences among individuals. The feel method is qualitative more than quantitative. The feel method involves moistening the soil, kneading the moistened soil mass with your fingers to mix the particles thoroughly, and feeling the particles to determine the texture. The accuracy of estimating soil texture by this method improves with experience. Examples of the soil textures using the feel method are provided in descriptive form.

### Determining the Soil Textural Class by the "Feel/Field" Method

The soil textural class can be estimated by observing and feeling the soil under dry, moist, and wet conditions. The size range of the separates and their feel when moist are listed in Table 4.

Table 4. USDA soil particle size ranges and feel under moist conditions.

| Soil Separate | Diameter (mm) | Feel: moist condition |
|---|---|---|
| Sand | 2.0 – 0.05 | Gritty |
| Silt | 0.05 – 0.002 | Smooth, velvety, buttery |
| Clay | < 0.002 | Sticky, plastic |

## Soil Structure

Soil structure is the arrangement of the individual soil particles into aggregates which are separated by surfaces of weakness. The structural aggregates, which are called peds, comprise several types depending on their shape: granular, blocky, prismatic, columnar, and platy. The definition has two parts: aggregation and separations. If a soil's condition does not satisfy both parts of the definition, it is structureless. Thus, not all soils have structure. The two structureless conditions are single grained (having no aggregation) and massive (having no separation patterns).

*Granular soil structure…* occurs most commonly in the A horizon. Granular structure forms as a result of the soil humus attracting strongly to the surface of the silt and clay particles of the soil. This attraction multiplied over many years creates aggregates. The binding between the humus of one aggregate and the next is less than the binding of the humus to the silt and clay particles. Consequently, the aggregates act independently. The humus causes the individual aggregates to arrange much as marbles would in a random arrangement with many voids or pore spaces between the aggregates. These pores allow for rapid water permeability. These same pores permit rapid air movement and allows for easy root penetration. Granular structure is optimized in the presence of the very fine roots of grasses. Granular structure can form within 50 to 100 years of exposing new parent material.

*Blocky soil structure…* is most commonly found in the B horizon. Blocky structure occurs as a result of the long, slow process of clay particles moving from the A horizon (eluviation) and leaching into the B horizon (illuviation). As these clay particles accumulate in the B horizon, they settle inside existing pores. Consequently, the soil pores become lined with these il uviated clay particles. With time, more of these pores become fil ed with clay, thus squeezing the pores tighter together and reducing water permeability, air movement and ease of root penetration. These individual aggregates take on a block-like appearance.

*Prismatic soil structure…* usually forms after blocky structure has been formed in the B horizon of a soil. Prismatic structure is usually associated with soils which have formed in semiarid and arid environments where the soil dries out to a considerable depth during some period of the year. This pul s the blocks apart and eventually leads to a whole group of blocks acting as a vertical prism. These prisms form zones of weakness between the prisms vertically. During the first rains of the wet season, water rapidly moves down along these prisms, but as the soil becomes wetter, the prisms expand, fil ing the voids between the prisms resulting in moderate water permeability. This causes restricted air movement and reduces the ease of root penetration through this horizon.

*Columnar soil structure…* occurs in the B horizon of some soils in semiarid and arid regions. Columnar structure only occurs where the soil has a high concentration of sodium on the soil cation exchange sites. The columns form in a similar manner to the formation of the soil prisms. However, as the soil continues to form, the sodium disperses the clays from the surface of the prism and causes these clays to move down the edges of the prisms. This causes a strong degree of sealing of the prisms resulting in slow to very slow water permeability, restricted air movement, and very difficult root penetration. Few plants can grow in such soil.

*Platy soil structure…* is relatively rare in native soils. Platy structure is most commonly formed as a result of compaction by vehicles, livestock, and humans. Platy structure is most commonly found in the A horizon of agricultural, urban, forest, and range soils under intensive management. The key factor is relatively horizontal layers of these soil aggregates.

*Single grain soil structure…* occurs where no grain is connected to any other grain. The best example is dune sand. Sands and silts in an alluvial (river deposit) or loess (wind deposit) may have a single grain structure. Single grain structure is a lack of structure since no true aggregates exist.

*Massive soil structure…* is really the lack of structure. As the term massive suggests, this is simply a mass of soil particles with no apparent repeating shape across the horizon. Massive structure usually occurs in the C horizon but may occur in other horizons if very little soil horizon development has occurred.

Soil structure is the second most important soil physical property. It influences water infiltration and percolation, aeration, erosion resistance, and ease of root penetration. The soil's structure is controlled by the soil's texture, organic matter content and form of organic compounds, plant and animal activity, and clay mineral content, and chemistry. Some common soil structure cementing agents are humus, aluminosilicate clay, iron and aluminum oxide clay, silica, and carbonates. Often, soil structure is easily altered by human activities such as tillage or compaction.

Soil structure and texture interact to control other soil properties. In Table 4, soil structure has a greater influence in fine textured soils than in coarse textured soils. This indicates structure is more prominent in fine soils than in coarse soils.

---

# 1.2: Activity 1 - Soil Formation

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

*Read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

*1) As best you can and in your own words, define, "soil."*

*2) Refer to the soil monoliths identified by your instructor at the front of the classroom. Using these monoliths for reference, please draw an interpretive diagram of soil by incorporating the terms PEDON, HORIZON/LAYER, and PROFILE together into one image. Label each of these key terms/parts on your diagram.*

*3) Please fill in the following blanks and answer the questions referring to each of the soil forming factors indicated below:*

| Soil forming factor | Contributing element |
| --- | --- |
| Climate | 1. ________________________<br>2. Precipitation<br>3. Evaporation |
| Organisms | 1. Human influence<br>2. _________________________<br>3. _________________________ |
| Relief | 1. _________________________<br>2. Erosion/sedimentation on the landscape |
| Parent Material | Give two examples of a parent material type:<br>1. __________________________<br>2. __________________________ |
| Time | Why would it be important to assess the<br>formation of soil over time? |

4) Indicate whether each of the following examples represents an ADDITION, LOSS, TRANSFORMATION, or TRANSLOCATION within the soil. Note: some answers are used more than once. (6 points)

a. Clay particles are moved by water moving from an upper E horizon to a lower B horizon within a soil profile…
b. The forces of nature have acted upon the soil over time, weathering sand sized particles into smaller clay sized particles within the top horizon of a soil profile…
c. Surface mineral soil material is washed away by the force of a monsoon…
d. Organic material is mixed into the upper 20cm of the soil profile by the activity of burrowing worms…
e. Dust particles fall on to the surface of a soil…
f. Nitrate is leached from the A horizon within the soil profile…

# 1.3: Activity 2 - Soil Horizons

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

*Read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

*1) What do the subscripts p, r, t, and k indicate when applied to soil horizons? (Refer to red field guidebook)*

p =

r =

t =

k =

*2) Which master soil horizon or layer is each subscript associated with in soils?*

*Horizon or layer*

p _______

r _______

t _______

k _______

*3) How does the presence of iron oxides affect soil color?*

4) *Which horizon (A, E, or B) is usually first to form as the soil develops?*

# 1.4: Activity 3 - Soil Color

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

*Read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

1) Obtain a Munsell Color Book.

2) Become familiar with the hue, value, chroma, and the name designations.

3) Turn the pages until the page (hue) approximates the overall soil color.

4) Determine the color of the soil samples on the laboratory bench. Record both the Munsel color notation and color name on the appropriate line below.

5) Compare the color chips in the Munsell Color Book with the color of the dry soil.

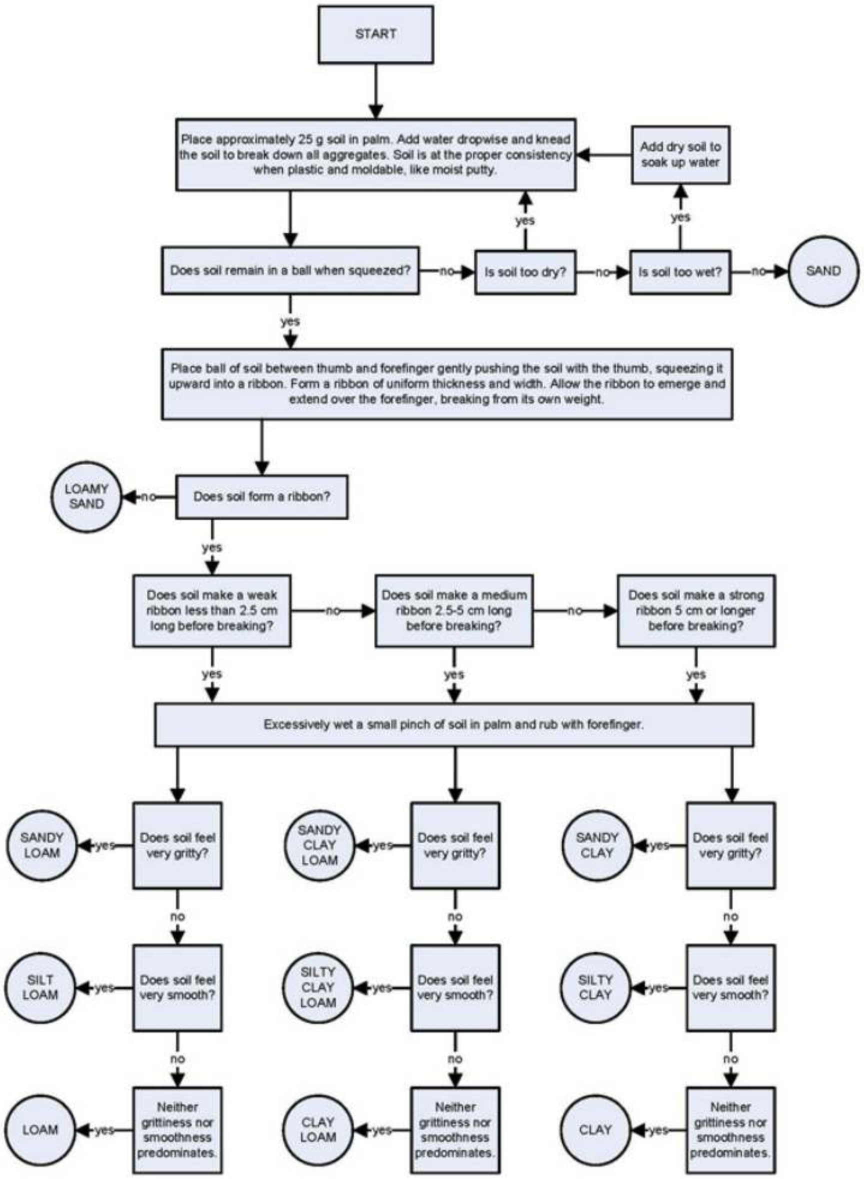
| *Dry Soil* | *Munsel Color Notation* | *Color Name* |
|---|---|---|
| A | | |
| B | | |
| C | | |

6) Moisten the soil and determine its Munsell Color in this new moisture condition. Record results on the appropriate line below.

| *Moist Soil* | *Munsel Color Notation* | *Color Name* |
|---|---|---|
| A | | |
| B | | |
| C | | |

*1) In what way did wetting each soil affect its color?*

*2) Which color notation (hue, value or chroma) is most affected by wetting the soil?*




USDA-NRCS, Texture by Feel, marked as public domain, more details on Wikimedia Commons

# 1.5: Activity 4 - Soil Texture

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

*Read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

*Known Soil Samples to be Identified:*

| Sample | Soil Characteristics (grittiness, stickiness, ribbon length, etc.) | USDA Textural Class |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |

*Unknown Soil Samples to be Identified:*

| Sample | Soil Characteristics (grittiness, stickiness, ribbon length, etc.) | USDA Textural Class |
|---|---|---|
| 1 | | |
| 2 | | |

*1) Define soil texture.*

*2) What differences do you notice between the feel of the sand and the feel of the silt separates?*

*3) Which soil separate will settle most rapidly to the bottom of the lake?*

*4) Practice determining the textural class for these soils:*

| Soil Sample | Sand % by mass | Silt | Clay | USDA Soil Textural Class |
|---|---|---|---|---|
| A | 65 | 25 | 10 | Sandy Loam |
| B | 40 | 40 | 20 | |
| C | 50 | 25 | 25 | |
| D | 10 | 70 | 20 | |
| E | 40 | 10 | 50 | |
| F | 17 | 46 | 37 | |

*5) What is the lowest clay percentage allowed for a texture to be classed as:*

| | |
|---|---|
| clay = | clay loam = |
| sandy clay loam = | sandy clay = |

*6) What is the lowest silt percentage allowed for a texture to be classed as:*

| | | |
|---|---|---|
| loam = | silt loam = | silt = |

*7) A dry soil sample weighing _25_ grams in total contains _8_ grams of sand, _15_ grams of clay, and the remainder is silt. Calculate the percentages of sand, silt and clay and determine the soil's textural class. Show the appropriate units and complete setup for each calculation of this problem.*

% Sand =

% Silt =

% Clay =

USDA Textural Class =

---

# 1.6: Activity 5 - Soil Structure

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

*Read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

1) Draw a picture of the various soil structures on display.

| | | | |
|---|---|---|---|
| Granular | Blocky | Prismatic | Columnar |
| Platy | Single Grain | Massive | |

*2) How can granular soil structure be distinguished from blocky structure?*

*3) How are soil texture and structure affected (if at all) by soil compaction?*

Texture is:

Structure is:

*4) Name five cementing agents important in the formation of soil structure.*

a.

b.

c.

d.

e.

5) Which type of soil structure is commonly found in the A horizon of a non-disturbed grassland soil? Why?

## REMINDERS/Assignments for next week’s lab:

a) Study for pre-lab Quiz on material from Lab #2: Soil Parent Materials and Mineralogy.

b) Your lab instructor will give you a soil sampling “kit” in order to take soil samples from a location of your choice in Laramie, WY - your backyard should do! You wil use this sampling “kit” to take your sample

1. A bulk density (BD) soil sample (using known volume metal BD ring stored in small sample bag)
2. Instructions for collecting bulk density measurements using core method: https://www.youtube.com/watch?v=E7BSZrJ-TDw&feature=youtu.be&t=1341
    i. Video should begin at 22:20, and watch through 25:28.
    ii. Record the ring number and ring volume on your sample bag
    iii. You only need to take 1 sample; this video instructs taking 3 samples per horizon.
3. Remember to record the coordinates (latitude, longitude) of this general location for reference. Please bring this soil sample to next week’s lab for preparation.

# CHAPTER OVERVIEW

## 2: Parent Materials and Mineralogy

**Learning Objectives**

- To understand the various types of soil parent materials that exist
- To identify the physical and chemical properties of common minerals and rocks
- To understand be able to recognize important soil weathering processes such as hydrolysis, carbonation, and redox reactions
- To recognize what different weathered geologic material looks like at various stages of weathering from rock, to parent material, to soil.

**GOAL**: To understand the importance of soil mineralogy and the fundamentals of soil parent materials and they play in soil formation.



**Additional resources**:

- Bil Nye The Science Guy, “Rock and Soil” - https://www.youtube.com/watch?v=34mquU3nBfY (length: 23:04)
- “Children’s” learning lesson on weathering- https://www.youtube.com/watch?v=R-Iak3Wvh9c (length: 4:05)

## 2.1: Introduction

Soils don't simply *exist* on the landscape; rather they grow, develop, erode, and slowly transform into other soils through time—a group of processes known collectively as pedogenesis. Pedogenesis begins with *parent material*, the stuff from which soils form. Although a small minority of soils develop in organic deposits, most derived from inorganic parent materials acted upon by *additions*, *losses*, *translocations*, and *transformations*

A major type of transformation is **weathering of geologic parent materials**. All mineral soils develop from the rocks and minerals of the earth's crust. Through weathering, minerals and rocks physically **disintegrate into smaller particle sizes**, and **chemicaly decompose into altered chemical and mineralogical products**. However, the original rock material commonly is transported or reworked by some mechanism before a soil is formed. Variations in the history of the initial material lead to a **range of types of soil parent materials** (Table 1). Additional y, these **weathering processes release elements**, including plant and animal nutrients, and convert primary minerals into clays.

Table 1. "Summary of transported parent materials" by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

| Mode of transportation | Mode of deposition | Name of parent material |
|---|---|---|
| Gravity | Gravity | Colluvium |
| Water | Stream | Alluvium |
| | Lake | Lacustrine |
| | Ocean | Marine |
| Ice | Ice | Till, moraine |
| | Meltwater | Outwash (alluvium, lacustrine) |
| Wind | Wind | Loess, dunes |

These parent materials continue to weather over time based on a function of soil forming factors and processes. Another major consideration for weathering potential of soil parent materials is hillslope position. Hillslope position references where on the landscape a soil is located (Figure 1). Hillslope positions essential y delegate the degree of slope and interaction with the groundwater table for the soils of a specific position location. These relationships between soil and slope, or the groundwater table, greatly influence weathering processes over time, increasing both physical and chemical weathering, depending on hil slope position.

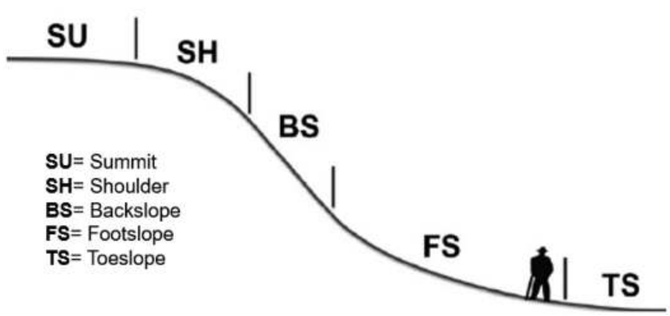



Figure 1. "Hill slope position across a landscape" Positions higher up and with a higher slope wil have better drainage and less interaction with the groundwater table, while those positions that are lower lying on the landscape have a lower slope and decreased drainage. Wysocki et al., 2000 and Schoeneberger et al., 2012.

### MINERALS

In geology and soil science, a mineral is a naturally occurring, inorganic, crystalline solid having a definite chemical composition and predictable physical properties. Of the six criteria included in this definition, three (naturally occurring, inorganic, and solid) need little elaboration; the remaining three are explained in succeeding paragraphs.

## Crystalinity of Minerals

Crystalline means that a mineral's atoms are arranged in an orderly and repeatable manner; they are not random. The atomic arrangement, which varies among mineral groups, contributes to several of the mineral's physical properties, including hardness and cleavage, which are explained under "Physical Properties of Minerals." In contrast, a substance having randomly arranged atoms is amorphous, or noncrystalline, and as such is not considered to be a mineral. A good example of amorphous material is the rock obsidian, a form of volcanic glass.

## Chemical Composition of Minerals

Minerals are made up of one or more elements, which give rise to definite chemical compositions (Figure 2). Although chemical formulas are precisely fixed for some minerals (e.g., quartz is SiO2 and orthoclase is KAlSi3O8), they can vary within a narrow range for other minerals (e.g., plagioclase ranges from NaAlSi3O8 to CaAl2Si2O8 because Na+ and Ca2+, which substitute for each other, occur together in varying proportions in the same mineral). Also, no matter how precise the formula, irregularities occur in nature, allowing impurities to sneak in. Note the elements and minerals in Figure 2. What do the four minerals have in common?

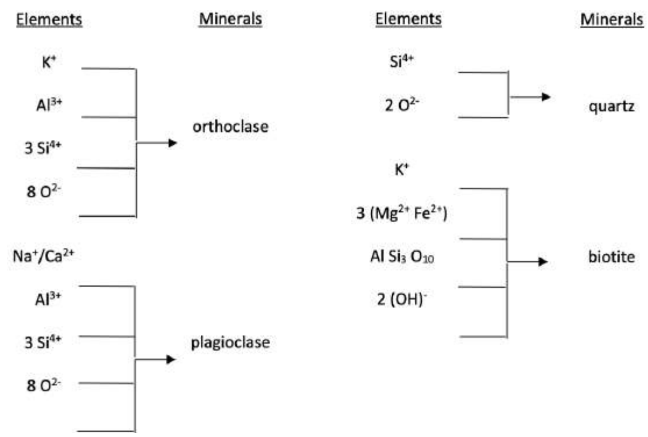



Figure 2. Elemental composition of four common minerals important in soil formation.

On a mass basis, nearly three-fourths of Earth's crust is made up of only two elements: oxygen and silicon; and on a volume basis, these two elements constitute more than 90%! The next six most common elements bring the totals to about 98.5 percent by mass, and to nearly 100 percent by volume (Table 2). Obviously, very little room is left for the remaining 100 or so elements, including most plant nutrients, found in the crust. How is it then that soils, nearly all of which derive ultimately from crustal weathering, can supply enough nutrient elements for nearly all terrestrial life, including three-fourths of humanity's food supply? Your work in this laboratory exercise should help you begin to understand and appreciate the answer to this question.

Table 2. The eight most common elements in the Earth's crust.

| Element | Ionic Formula | Mass Percent | Volume Percent |
|---|---|---|---|
| Oxygen | $O^{2-}$ | 46.60 | 91.97 |
| Silicon | $Si^{4+}$ | 27.72 | 0.80 |
| Aluminum | $Al^{3+}$ | 8.13 | 0.77 |
| Iron | $Fe^{2+}$ & $Fe^{3+}$ | 5.00 | 0.68 |
| Calcium | $Ca^{2+}$ | 3.63 | 1.48 |
| Sodium | $Na^{+}$ | 2.83 | 1.60 |
| Potassium | $K^{+}$ | 2.59 | 2.14 |
| Magnesium | $Mg^{2+}$ | 2.09 | 0.56 |

## Mineral Classification Based on Chemical Composition

Most minerals are grouped into seven classes based on their fundamental anionic unit (Table 3). (A few other classes exist, but these can be ignored for this laboratory). Of these, the silicates are by far the most common; nonetheless weathering products of others can be equal y vital.

Table 3. Classification and composition of selected minerals important in soil science.

| Mineral Class | Example | Chemical Composition (specimen #) | Comments |
|---|---|---|---|
| Sulfides | 1) pyrite<br>2) sphalerite | $FeS_2$ (19)<br>ZnS (17) | readily oxidized in moist soils |
| Oxides | hematite | $Fe_2O_3$ (15) | readily oxidized, producing red colors |
| Halides | 1) halite<br>2) sylvite | NaCl (18)<br>KCl | rock salt; sometimes found in desert soils |
| Carbonates | 1) calcite<br>2) dolomite | $CaCO_3$ (13)<br>$CaMg(CO_3)_2$ | 1) calcareous; reacts to acid; weathers easily in moist soils<br>2) calcareous; less reactive than calcite |
| Sulfates | gypsum | $CaSO_4$•$2H_2O$ (20) | a common agricultural amendment; sometimes found in desert soils |
| Phosphates | apatite | $Ca_5(PO_4)3(F,Cl,OH)$ (8) | the only significant source of phosphorus |
| Silicates | olivine | $(Mg, Fe)2SiO_4$ | most easily weathered of the silicates |
| | pyroxene: augite | $(Ca, Na)(Mg, Fe, Al)(Si, Al)2O_6$ (12) | susceptible to oxidation and hydration |
| | amphibole: hornblende | $(Ca,Na)2\text{-}3(Mg,Fe,Al)5Si_6(Si,Al)2O_{22}(OH)2$ (11) | susceptible to oxidation and hydration, but more resistant than augite |
| | micas:<br>1) muscovite<br>2) biotite | 1) $KAl_2(AlSi_3O_{10})(OH)2$ (6)<br>2) $K(Mg, Fe)3(AlSi_3O_{10})(OH)2$ (7) | 1) soft, but strongly resists chemical weathering<br>2) soft; weathers more easily than muscovite |
| | feldspars:<br>1) orthoclase<br>2) plagioclase | 1) $KAlSi_3O_8$ (9)<br>2) $Na(AlSi_3O_8) \rightarrow Ca(Al_2Si_2O_8)$ (10) | Most common minerals<br>1)hard, resistant<br>2)hard, weathers |
| | quartz | $SiO_2$ (4) | hard and most resistant to weathering |

## Physical Properties of Minerals

*Color:* Minerals exist in nearly every color, and although color is easy to determine, it might not be reliable for identifying a mineral. For example, pyrite is nearly always brassy yellow, but quartz can range across several hues, values, and chromas from colorless to white, pink, purple, and gray. In some minerals, color can be strongly influenced by impurities.

*Luster:* independent of a mineral's color and determined by the nature of light reflected from a mineral's surface. Most lusters fall into two main groups: metallic and nonmetallic. Metallic lusters are typical of minerals that strongly absorb light, and as a result are opaque, even in very thin pieces. These minerals tend to look like metals, even though their surfaces might range from shiny to dull. Nonmetallic lusters are seen in minerals that allow light to pass through thinly cut slices. Surfaces of nonmetallic minerals might be brilliant like diamond, glassy like quartz, waxy like serpentine, or earthy like clay.

*Cleavage and fracture:* Cleavage is a mineral's tendency to break along certain predictable directions when the mineral is struck by a hammer. The resulting cleavage surfaces might be smooth and distinct, or they might be rough and indistinct, depending on the type of mineral. Different minerals also cleave along different directions and at different angles, depending on the type and orientation of atomic bonding. Although the number of possible cleavage directions is 1, 2, 3, 4, or 6, we will focus only on minerals that have 1 (e.g., biotite), 2 (e.g., orthoclase), and 3 (e.g., calcite) directions (Figure 3). Some minerals, when hit by a hammer, do not break along predictable planes: they simply shatter in any direction. These minerals are said to fracture, rather than cleave. Quartz is a good example of a mineral that exhibits fracture.

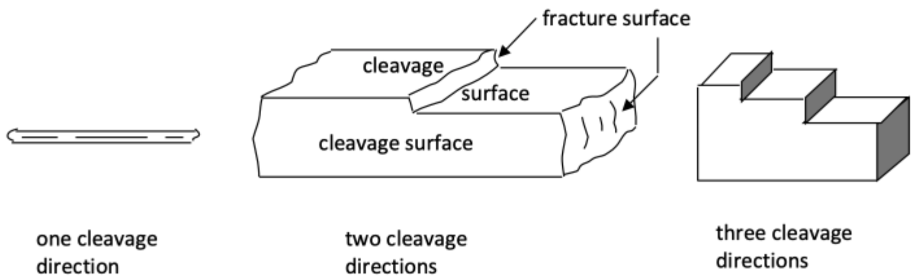



Figure 3. Examples of mineral cleavage.

*Hardness:* Hardness is determined by the resistance of a mineral's surface to scratching by various instruments of known hardness. It is judged by the Mohs hardness scale, which uses certain reference minerals ranked from 1 (soft) to 10 (hard): (see next page

## *Mohs Hardness Scale*

1. Talc (easily "scratched" by rubbing between fingers, giving a soapy feel)
2. Gypsum (easily scratched by a fingernail)
3. Calcite (same hardness as a penny)
4. Fluorite
5. Apatite (a bit softer than a pocket knife blade)
6. Orthoclase (harder than a knife blade, but slightly softer than glass)
7. Quartz (harder than both a knife blade and glass)
8. Topaz
9. Corundum
10. Diamond

(Soil minerals are very rarely harder than 7)

## Essential elements for plants and animals

Essential elements are those that organisms need to grow and complete their life cycles. For plants, sixteen elements are universal y recognized as essential; nonetheless research conducted in the late 20th century suggests that the number is eighteen or perhaps even greater. We wil consider that plants require eighteen elements (Table 4), although you should understand that many plants, depending on their species, take up more than they seem to need.

A mnemonic phrase can help you memorize the 18 elements:

*C HOPKNS CaFe Mg B Mn CuZn Cl CoMo Ni*

Translated, this reads "C Hopkns café, managed by "mine" cousins Clyde, Como, and Nicky."

Note that of the eight most common elements in Earth's crust, only five, oxygen, iron, calcium, potassium, and magnesium, are among the 18 essential elements (Table 4); and the first of these, oxygen, is supplied by O2 in the atmosphere, **not** by weathering of minerals and rocks. Of the thirteen remaining essential elements, hydrogen comes from water, carbon comes from carbon dioxide (CO2) in the atmosphere, and nitrogen is maintained by cycling of organic matter. (Nitrogen first is made available to plants by fixation from the atmosphere.) The remaining ten elements, phosphorus, sulfur, boron, manganese, copper, zinc, chlorine, molybdenum, nickel, and cobalt derive from weathering of minerals and rocks

Table 4. Essential elements for plants.

| Macronutrients | | | Micronutrients | | |
|---|---|---|---|---|---|
| Element | Atomic Symbol | Plant Available Form | Element | Atomic Symbol | Plant Available Form |
| carbon | C | $CO_2$ | iron | Fe | $Fe^{2+}$, $Fe^{3+}$ |
| hydrogen | H | $H^+$ | manganese | Mn | $Mn^{2+}$ |
| oxygen | O | $O_2$, $H_2O$ | boron | B | $H_3BO_3$ |
| nitrogen | M | $NH_4^+$, $NO_3^-$ | zinc | Zn | $Zn^{2+}$ |
| phosphorus | P | $H_2PO_4^-$, $HPO_4^{2-}$ | copper | Cu | $Cu^{2+}$ |
| potassium | K | $K^+$ | chlorine | Cl | $Cl^-$ |
| calcium | Ca | $Ca^{2+}$ | cobalt | Co | $Co^{2+}$ |
| magnesium | Mg | $Mg^{2+}$ | molybdenum | Mo | $MoO_4^{2-}$ |
| sulfur | S | $SO_4^{2-}$ | nickel | Ni | $Ni^{2+}$ |

In addition to the 18 elements required by plants, animals also require arsenic (As), chromium (Cr), fluorine (F), iodine (I), lithium (Li), sodium (Na), selenium (Se), silicon (Si), and tin (Sn). Herbivorous animals obtain these elements by eating plants, which take up the elements, even though the plant might not need them. Carnivorous animals, in turn, obtain the elements by preying on other animals.

Regardless of whether the elements are required by plants or animals, all except carbon, hydrogen, oxygen, and nitrogen, are made available initially by weathering of minerals. The elements gradually become concentrated in the biosphere through biogeochemical cycles, including the carbon and nitrogen cycles, which will be covered in a later laboratory.

## ROCKS

The most common rocks are consolidated assemblages of minerals, but a few (e.g., obsidian, pumice, and coal) comprise non-crystalline (hence, nonmineral) materials. Despite the great number of possible compositions and arrangements, rocks can be divided into three categories based on their mode of formation: igneous, sedimentary, and metamorphic.

### Igneous Rocks

*Intrusive and Extrusive:* Igneous rocks form when molten material called magma cools and solidifies.

Although the magma originates tens of kilometers below Earth's surface, it can solidify at any depth from its depth of origin to the surface. Magma that remains at depth while cooling and solidifying forms igneous intrusive rocks. Because of extremely slow cooling, minerals can grow to macroscopic size, and can be readily identified in a hand specimen.

Instead of remaining deep throughout the cooling process, some magmas erupt to the surface, where they cool and solidify rapidly. The resulting igneous extrusive rocks can be glassy (i.e., amorphous) or microcrystalline, although many contain a smattering of macrocrystals that formed before eruption. In erupting, the magma might ooze toward the surface as lava, or it might explode violently into the atmosphere, forming pumice and volcanic ash.

*<u>Felsic and Mafic:</u>* In addition to having distinctively different crystal sizes, igneous rocks also vary in mineralogical composition because of chemical differences among magmas. Some rocks are dominated by quartz and orthoclase (potassium-rich feldspar) because they derived from magma that was rich in silica and potassium. These rocks, which tend to be light colored, are called felsic. Other igneous rocks have little or no quartz or orthoclase, but instead are characterized by calcic plagioclase (calcium-rich feldspar) and ferromagnesian minerals (e.g., augite and hornblende). These are called mafic and are dark colored. Other rocks of intermediate compositions can be found between these extremes.

## Classification of Igneous Rocks

The textural trend caused by varying rates of cooling, combined with the mineralogical trend resulting from chemical differences in magma provide the basis for classifying igneous rocks (Table 5). Selected elements also combine to form minerals, which then combine to form a common igneous intrusive rock (Table 6).

Accessory minerals, which can be significant, also vary from felsic to mafic. Of the micas, muscovite is felsic, and biotite is more mafic. As a result, muscovite is found in felsic rocks, including true granite, whereas biotite can occur in rocks ranging from felsic to moderately mafic. An important rock of intermediate composition is granodiorite, which has a characteristic salt-and-pepper appearance derived from light colored quartz and feldspars, especially sodic plagioclase, combined with dark colored biotite. Olivine, a strongly mafic mineral, and augite, which is slightly less mafic, are common constituents of gabbro and basalt.

Table 5. Classification of igneous rocks

| | | | |
|---|---|---|---|
| | Silica - $SiO_2$ | | |
| | | | Mg - magnesium and Fe - iron |
| | K-feldspar (orthoclase) | Na-feldspar (plagioclase) | Ca-feldspar (plagioclase) |
| | Felsic | Intermediate | Mafic |
| Intrusive (macrocrystalline) | **granite** | **granodiorite** | **gabbro** |
| | | other rocks of intermediate composition | |
| Extrusive (microcrystalline) | **rhyolite** | | **basalt** |

Table 6. An example of elements combining to form minerals and minerals combining to form an igneous rock.

| Elements → | Minerals → | Rock |
|---|---|---|
| $K^+$, $Al^{3+}$, 3 $Si^{4+}$, 8 $O^{2-}$ | orthoclase | granite |
| $Na^+/Ca^{2+}$, $Al^{3+}$, 3 $Si^{4+}$, 8 $O^{2-}$ | plagioclase | |
| $Si^{4+}$, 2 $O^{2-}$ | quartz | |
| $K^+$, 3 $(Mg^{2+} Fe^{2+})$, Al $Si_3$ $O_{10}$, 2 $(OH)^-$ | biotite | |

## Sedimentary Rocks

Sedimentary rocks, which make up the bulk of Earth's continental crust, can be either clastic (i.e., fragmental) or nonclastic (i.e., nonfragmental). See Table 7 for examples.

*Clastic rock:* consist of fragments of previously existing rocks (igneous, sedimentary, or metamorphic) that have been transported to a new location (often an ocean bottom), where they were deposited and buried layer upon layer, and cemented together. The deposits can be several thousand meters thick!

The fragments, or clasts, can vary in size to include clay, silt, sand, gravel, and cobbles.

Nonclastic rock: form by chemical precipitation of dissolved salts and by biochemical precipitation of organically derived compounds in water, most commonly on the floors of shallow seas. Organisms that generate nonclastic rocks include bacteria, algae, diatoms, corals, and mollusks. The most common nonclastic sedimentary rocks are limestone and dolomite (also called dolomitic limestone). Others include rock gypsum, chert, and coal.

Although the two major categories are recognized, most sedimentary rocks are a combination of clastic and nonclastic, nonetheless they usually are dominantly one or the other. For example, the sand grains in sandstone are clastic, but the cement that holds them together can be nonclastic.

Table 7. Classification of sedimentary rocks.

| **Clastic** | | **Nonclastic** | |
|---|---|---|---|
| **Dominant Constituent** | **Sedimentary Rock** | **Dominant Constituent** | **Sedimentary Rock** |
| clay | claystone | calcite (CaCO3) | limestone |
| silt | siltstone | dolomite (CaMg)(CO3)2 | dolomite |
| mud (silt + clay) | mudstone | gypsum (CaSO4•2H2O) | gypsum |
| thinly layered mud | shale | microcrystalline quartz (SiO2) | chert |
| sand (≥ 50%): mostly quartz, feldspars, micas<br>sand: 50-85% sand with remainder mud and possibly some pebbles<br>sand: > 85% sand with remainder mud and possibly pebbles | sandstones<br>wacke (dirty sandstone)<br>arenite (clean sandstone) | | |
| gravel (pebbles) with sand and mud; quartz, orthoclase, quartzite | conglomerate | | |

## Metamorphic Rocks

Metamorphic rocks form primarily by the application of extremely high heat and pressure to some previously existing rock. The original rock may be igneous, sedimentary, or even metamorphic, but sedimentary rocks are most susceptible to metamorphosis. Metamorphic rocks can be either foliated or nonfoliated. Foliated rocks consist of minerals that are aligned or oriented to yield a somewhat stratified or layered appearance, whereas the minerals in nonfoliated rocks are about equally arranged in all directions, giving them a more uniformly massive appearance (Table 8).

Table 8. Classification of metamorphic rocks.

| Foliated | | |
|---|---|---|
| *Metamorphic Rock* | *Common Original Rock* | *Appearance/Comments* |
| slate | shale | strongly stratified (layered), flat; often with very fine quartz and mica; cleaves into sheets, but denser than shale |
| schist | shale or other slate | wavy foliation; often with micas, quartz, feldspars |
| gneiss (pronounced "nice") | granitic rocks | minerals oriented to give more faint stratification than schist; often contains the same minerals as its granitic counterpart |
| **Nonfoliated** | | |
| marble | limestone | calcite cleavage usually visible; fizzes to release CO2 when tested with HCl |
| quartzite | quartz arenite | hard; very resistant to weathering |
| serpentinite | peridotite (an ultramafic igneous rock) | greenish assemblage of serpentine minerals; high magnesium; occurs intermittently along west coast of North America, and smaller areas of the East Coast |

## WEATHERING

Weathering breaks rocks and minerals down, resulting in the production of soils. Weathering occurs via two processes: physical disintegration (breaking into smaller pieces) and chemical decomposition (changing the nature of the minerals themselves).

**Physical disintegration** causes rock masses to split apart or to abrade and wear away from the larger rock surface. Freezing and thawing, abrasion by particles suspended in wind or water, and grinding caused by glaciers result in disintegration. Repeated actions of these processes cause stresses, which eventually break and erode rock surfaces. Physical weathering usually precedes or occurs in concert with the chemical decomposition process. With a decrease in the size of individual particles, the total number of corners and edges and the total surface area of the rock mass greatly increase.

### Chemical decomposition

Chemical decomposition progresses most rapidly when more surface area is available for chemical reactions to occur. Warm and wet environments enhance chemical decomposition. The smaller the particles, the greater the surface area of a given volume of rock (the greater the total exposed corners and edges) and the greater the rate of chemical decomposition. The total number of corners exposed to weathering processes is the major factor in the determination of weathering rates. This is because a corner has three surfaces and three edges for chemical attack. Chemical weathering is a combination of five major processes: carbonation, hydration, hydrolysis, oxidation-reduction (redox), and solution.

Hydrolysis and particle size: Hydrolysis is a chemical decomposition process involving the splitting of water molecules during a reaction. A hydrolysis reaction can be easily identified by looking for water on the left side of a chemical equation and the absence of water (but the formation of $H^+$ and/or $OH^-$) on the right side of the equation. All minerals weather by hydrolysis. The hydrolysis reaction is particularly evident with silicate minerals (e. g. feldspars and micas). Hydrolysis is the primary reaction resulting in the release of most plant nutrient elements from minerals. The mineral orthoclase will weather by hydrolysis.

$$KAlSi_3O_8 + H_2O \rightarrow HAlSi_3O8 + K^+ + OH^-$$

$$\textit{Orthoclase + Water} \rightarrow \textit{Al-silicate mineral + Potassium ion + Hydroxide ion}$$

The potassium cation ($K^+$) released by this hydrolysis reaction is soluble in water and can be adsorbed by the soil clay minerals and organic colloids, used by plants, or be removed (leached) by the drainage water. The aluminum silicate compound may crystallize into a clay mineral (e. g. kaolinite). This natural chemical weathering process occurs at a very slow but continual rate in all rocks, parent materials, and soils. The smaller the original mineral, the faster the hydrolysis reaction will occur. The hydroxide ion ($OH^-$) will increase the pH. When a glacier grinds rocks with glacial ice (water), the grinding is a physical disintegration process. However, the resulting hydrolysis reaction of the fine particles hydrolyzing with the water causes the glacial till to have a high pH (abrasion pH). Initially, the pH of the glacial till will be 9 or 10, but as the glacial till absorbs carbon dioxide from the air, the pH will drop.

*Carbonation and Solution:* The metabolic activities of plant roots and microorganisms produce an abundance of $CO_2$ within soil pores. This $CO_2$ reacts with soil water to produce most of the carbonic acid found in soils.

$$CO_2 + H_2O \leftrightarrow H_2CO_3$$

*Carbon Dioxide + Water ↔ Carbonic acid*

The carbonic acid in the soil water continually reacts with minerals as the water percolates through soils and rocks. Carbonic acid, a weak acid, is the most common acid found in soils. Carbonic acid can ionize into acidic hydrogen ions ($H^+$) and bicarbonate ($HCO_3^-$):

$$H_2CO_3 \leftrightarrow H^+ + HCO_3$$

*Carbonic acid ↔ Acidic hydrogen ion + Bicarbonate ion*

At pH < 6, this reaction tends to go more to the left than to the right, indicating carbonic acid is a weak acid and does not produce very many acidic hydrogen ions. Carbonic acid is effective in accelerating the chemical decomposition processes of minerals because nature continually provides rainwater and carbon dioxide. Thus, rainwater drives this reaction to the right. As the rainwater moves through the soil, it carries soluble bicarbonate ions deeper into the soil profile and deposits the acidic hydrogen ions on the soil surfaces. The law of mass action allows the soil to eventually become acidic with time of weathering as rainfall drives the above reaction to the right.

As a result of a glacier grinding rocks, the hydrolysis reaction results in the glacial till containing soluble Ca2+ ions and OH- ions (which causes a high pH, greater than 8.3). As the glacial till is exposed to carbonic acid, the glacial till undergoes two carbonation reactions. The first reaction process is quite rapid, while the second reaction is slow and requires time for completion. The first carbonation reaction is

$$Ca^{2+} + 2OH^- + H_2CO^3 \rightarrow CaCO_3 + 2H_2O$$

*Soluble calcium + Soluble hydroxide + Carbonic acid → Low soluble calcite + Water*

The second reaction is:

$$CaCO_3 + H_2CO_3 \rightarrow Ca(HCO_3)_2$$

*Calcite + Carbonic acid → Soluble calcium bicarbonate*

The calcium bicarbonate dissolves slowly and releases soluble calcium ions ($Ca^{2+}$) for plant uptake or possible leaching downward through the soil when excessive rainfall or irrigation occurs. The loss of the calcite minerals (the chief mineral in limestone) eventually leads to the development of acidic soils, carbonate hardpans, and the formation of huge underground caverns (e. g. Mammoth Cave and Carlsbad Caverns). The cave one walks through is the hole remaining after the soluble calcium bicarbonate has left the cavity where the carbonic acid dissolved the limestone rock.

The soluble calcium and bicarbonate move downward and enter the ground water, which eventually emerges as water in streams flowing to the ocean. The presence of the calcium bicarbonate in the ground water is the major reason limestone ground water is termed “hard water”.

Eventually, the second reaction has two major effects in a high rainfall environment. First, the surface soil will become acidic and the pH will decrease due to increased rainfall and $CO_2$ production ($H_2CO_3$). Second, soluble calcium is made available to plants. However, further rainfall will leach the soluble calcium bicarbonate downward.

Eventually, the soil will become depleted of calcium ($Ca^{2+}$). The same phenomenon will be true for magnesium ($Mg^{2+}$), potassium ($K^+$), and sodium ($Na^+$) cations released to the soil by the hydrolysis of various minerals. This process results in a loss of overall plant nutrition and soil fertility.

*Reduction-oxidation (redox) reactions:* involve the transfer of electrons from one reactant to another. In every redox reaction, some substance becomes oxidized and some other substance becomes reduced by the transfer of the electron. The substance losing the electron is oxidized and the component accepting the electrons becomes reduced. Commonly, but not always, oxygen serves as the oxidizing agent.

Oxygen combines with an element in a mineral, such as iron ($Fe^{2+}$), causing the iron to give up some of its electrons, which are accepted by oxygen. The iron becomes oxidized while the oxygen becomes reduced. These electron transfers constitute a form of chemical weathering, which disrupts the mineral's atomic structure, releasing several elements, and leading to the development of new compounds including clay minerals.

Although redox reactions take place continuously in soils, their reaction rates can be very slow and unnoticeable. If a soil is moist and well aerated, iron tends to become oxidized ($Fe^{3+}$, loses electrons to oxygen), but if air (oxygen gas) is absent, as occurs with water-saturated soil, the iron becomes reduced ($Fe^{2+}$, gains electrons). The extent of either oxidation or reduction in soils is manifested in the color of the soil. Oxidized iron ($Fe^{3+}$) occurs where oxygen is present in well-drained soils and produces red, yellow, or brown colors in soils. Reduced iron ($Fe^{2+}$) exists in flooded or very poorly drained soils and produces black, gray, olive, and blue colors. Alternating periods of oxidation and reduction, caused by fluctuating water levels in a soil, result in mottling (blotches of red and yellow mixed with gray colors) to occur. Continuous strongly reducing conditions caused by long-term water-logging forms gleyed conditions. Gleyed soils have dark gray to blue to black soil colors.

$$Fe^{2+} \xleftrightarrow{O_2} Fe^{3+}$$

*Reduced (gray soil colors) ↔ Oxidized (red and yellow soil colors)*

*Read through and complete the folowing activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work wil be accepted.*

---

# 2.2: Activity 2 - Minerals

You will need to study the mineral specimens provided to fill in the blanks in the table below. Use the following guidelines for completing the table:

- **Color**: Describe what you see. Munsell color designations are not necessary.
- **Luster**: Write in either "M" for metallic or "N" for nonmetallic.
- **Hardness**: Soft (S) minerals can be scratched by a fingernail. Medium (M) minerals can be scratched by a penny. Hard (H) minerals cannot be scratched by a penny and can scratch glass.
- **Cleavage**: Note whether present (1, 2, or 3 directions) or absent (0 directions).
- **Plant-available nutrients**: Refer to the list of essential elements and to Tables 3 and 4. Write in the chemical symbol of nutrients that are released and used by plants by weathering of minerals.

Table 3

| Mineral | Color | Luster (M or N) | Hardness (S, M, or H) | Cleavage (yes/no) | Plant-available nutrients from Minerals (Table 4) (atomic symbol & charge) |
|---|---|---|---|---|---|
| pyrite | | | | | |
| calcite | | | | | |
| gypsum | | | | | |
| hornblende | | | | | |
| muscovite | | | | | |
| plagioclase | | | | | |
| orthoclase | | | | | |
| quartz | | | | | |

1) Which of the minerals in Table 3 is most resistant to weathering?

2) Of the eight most common elements in the earth's crust, which ones are essential elements that are released to plants by the weathering of minerals?

_______________ _______________ _______________ _______________

3) Name the source of each of the following plant-essential elements:

C _______________

H _______________

O _______________

N _______________

# 2.3: Activity 2 - Rocks

Read the background information presented in this exercise, and study the minerals and rocks provided to fill in the blanks in the Properties of Rocks Table. Give the class as igneous intrusive (Ii), igneous extrusive (Ie), sedimentary (S), or metamorphic (M). List the crystal or grain size as microscopic (Mi) if the crystals or grains are too small to identify without a microscope, or macroscopic (Ma) if the crystals or grains are recognizable without a microscope.

*Exercise: Fill in the properties of the following rocks provided in the rock and mineral kits.*

*Ii=igneous intrusive, Ie=Igneous extrusive, S=sedimentary, M=Metamorphic, Mi=microcrystalline, Ma=macrocrystalline.*

| Rock | Class (Ii, Ie, S, M) | Color | Crystal or grain size (Mi, Ma) | Principal Constituents or Minerals |
|---|---|---|---|---|
| granite | | | | |
| basalt | | | | |
| sandstone | | | | |
| schist | | | | |
| limestone | | | | |
| chert | | | | |
| conglomerate | | | | |
| marble | | | | |
| gneiss | | | | |
| shale | | | | |

# 2.4: Activity 3 - Weathering

## *Part 1*

Your instructor has set up 2 beakers on a laboratory bench. Each beaker has a rock immersed in some type of liquid. Beaker #1 is filled with soda water, while beaker #2 contains a soil ped. Record the pH of the soda water, then submerge the ped into the soda water beaker. After the reaction has subsided, measure the pH of the solution. Record initial and final pH of the solution.

Initial pH: _________

Final pH: _________

1. *What are your predictions for what will happen when the liquids are added?*
2. *List your observations:*
3. *Explain the chemical process you observed:*

## *Part 2*

Your instructor has set out pictures detailing redoximorphic features displaying Oxidation and Reduction reactions. Observe each photo and detail your observations in the section below.

1. *Observe the picture on display for gleyed soils (Image 1). Describe the appearance of the gleyed soil.*
2. *Observe the colors of the mottled soil on display (Image 2). Describe the appearance of the mottled soil.*
3. *What are the physical (i.e. color) and chemical (i.e. form of Fe) properties of a gleyed/reduced soil?*
4. *What environmental condition causes soils to become gleyed?*
5. *In the field, what soil topographic or slope position (i.e. summit, backslope, or toeslope) would be most conducive to the formation of reducing conditions or gleyed soils? Why?*
6. *Most soils do NOT have gleyed horizons. If a gleyed horizon exists, which soil horizon is most commonly gleyed/reduced in a soil (Assume this soil has an impermeable layer at 100 cm)?*
7. *Explain why this horizon (from Q #6) would be most commonly reduced or gleyed.*
8. *Soil may have a mottled condition associated with a fluctuating water table. What are the physical and chemical properties of a mottled soil? What happens when the water table rises and falls in the mottled soil zone?*
9. *Well oxidized soils are associated with what soil drainage condition? (See page 1-11 in the Red Book)*
    - *In the field, what soil topographic or slope position (i.e. summit, backslope, or toeslope) would be most conducive to the formation of strongly oxidizing conditions in a soil? Why?*
10. *For most soils, which is likely to have the most oxides, and most likely to have an oxidized horizon? Why?*

---

# 2.5: Activity 4- Rocks to Parent Material

## Development of rocks into parent material that becomes soil

As mentioned above, inorganic parent materials are typically derived from a variety of geological species. These parent materials are typically identified by their mode of transportation (i.e. colluvium transported by gravity, or loess transported by wind), however, it is important to recognize how specific rock types physically weather in order to be able to identify parent materials properly in the field.

Observe the trays of parent materials and soil for the granite and sandstone rocks on display. The first tray contains the fresh rocks before being weathered, the second tray contains the parent material of the soil formed from this rock, and the third tray contains the soil formed from the parent material derived from this rock type.

1) List the main minerals in each type of rock.

Granite:

Sandstone:

2) What main physical changes (particle size and color) have occurred in the stages from rock to weathered rock to soil?

3) Which fraction—rock, weathered rock, or soil (circle one)—is most susceptible to further physical and chemical weathering? Why?

4) You will drop some hydrochloric acid (HCl) (a few drops) on each fraction (rock, weathered rock, and soil). Indicate which materials fizz by filling in the table below with a “Y” for yes and an “N” for no.

| **Rock Type** | **Rock (R)** | **Weathered rock parent material (Cr)** | **Soil** |
|---|---|---|---|
| Granite | | | |
| Sandstone | | | |

5) What is the reason (which reaction is responsible) for the fizzing?

## REMINDERS/Assignments for next week’s lab:

a) Study for pre-lab Quiz on material from Lab #3: Soil Taxonomy.

b) Complete pre-class activity: classified location exercise (Lab 3) c) Next week we will prep bulk density samples for an upcoming lab on Soil Physical Properties.

c) Next week we will prep bulk density samples for an upcoming lab on Soil Physical Properties.

# CHAPTER OVERVIEW

## 3: Soil Taxonomy

**Learning Objectives**

- To be able to identify epipedons and endopedons
- To become familiar with the 12 soil orders
- To understand the structure of Soil Taxonomy
- To begin to understand some of the broader applications and importance of Soil Taxonomy and classification of soils

**GOAL**: To understand the main soil factors that contribute to the classification of a soil and how to use the system of Soil Taxonomy.



**Additional resources**:

- The University of Idaho, “Twelve soil orders” - https://www.uidaho.edu/cals/soil-orders
- USDA-NRCS link to download the FREE .pdf of “Keys to Soil Taxonomy”-
- https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053580
- This lab adapted from Moorberg, Colby J. and Crouse, David A., "Soils Laboratory Manual, K-State Edition" (2017). NPP eBooks. 15. https://newprairiepress.org/ebooks/15 licensed under CC by 4.0

# 3.1: Introduction to Soil Taxonomy

The word, "taxonomy" is based on the Greek words "taxis", meaning arrangement; and "nomia", meaning method. In biology, taxonomy refers to a hierarchical system in which organisms are grouped based on shared characteristics, with domains and kingdoms at the top of the hierarchy, and genus and species at the lowest levels. Similarly, Soil Taxonomy is a hierarchical system used to group soils based on observable or measurable characteristics. A common application of soil classification (the act of identifying the taxonomic classification for a given soil) is to develop models of how soils of different classifications associate with one another within a landscape, which can eventually be used in soil mapping. The primary concepts of soil classification using Soil Taxonomy will be reviewed in this lab, followed by an overview of the Web Soil Survey (United States Department of Agriculture Natural Resources Conservation Service, 2016).

Table 1. "Explanation of the Ap horizon description" by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

| Morphological property | Description | Morphological property | Description |
|---|---|---|---|
| Horizon designation | Ap | Structure grade | Moderate |
| Upper depth | 0 in | Structure size | Medium |
| Lower depth | 9 in | Structure type (shape) | Granular |
| Color name | Dark grayish brown | Moist consistence | very friable |
| Munsell hue | 10YR | Roots | Many fine roots |
| Munsell value | 4 | pH | Slightly acid |
| Munsell chroma | 2 | Boundary | clear smooth |
| Textural class | Silt loam | | |

### Completing a soil profile description involves a systematic approach:

- Observing the landscape setting.
- Examining the morphological features like texture, structure, color, consistence, etc. of the soil to distinguish any layers or horizons.
- Describing in detail the texture, structure, color, consistence, and other features of each horizon.
- Assigning horizon designations to each layer.
- *Classifying the soil on the basis of its morphology and horizonation.*

## THE TAXONOMICAL SYSTEM OF SOIL

A comprehensive classification system is important for any science: soil science, plant science, biology, geology, among many others. Effective taxonomy allows us to organize knowledge and learn new relationships. Soil Taxonomy helps in extrapolating soil management research among similar soils around the world. Soil Taxonomy is a quantitative system based on soil properties that can be observed or measured, organized in a hierarchy based on six categories beginning with 12 broad soil orders and narrowing in specificity to more than 23,000 series. The organization of a taxonomic name by category is illustrated in Figure 1.

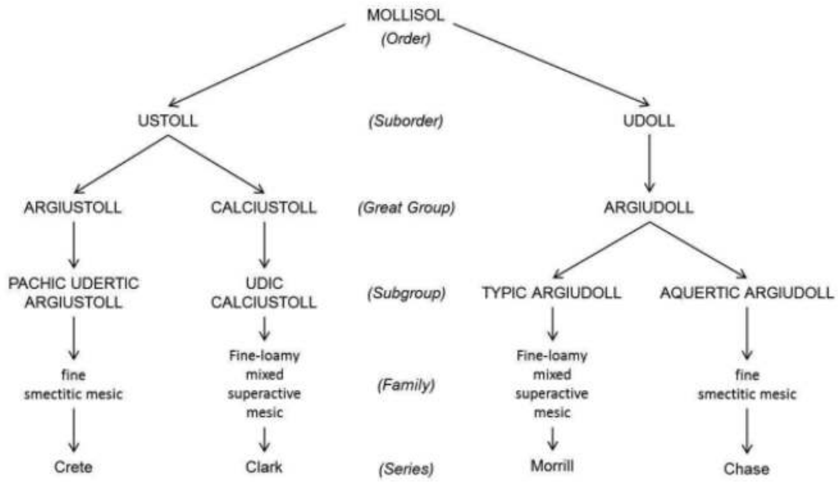



Figure 1. “Organization of Soil Taxonomy with examples” by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

## IDENTIFICATION OF THE TAXONOMIC CLASS OF A SOIL

Classification of soils is determined using the systematic approach outlined in the *Keys to Soil Taxonomy*. Individuals must begin with the “Key to Soil Orders” and eliminate, one by one, the classes including criteria which do not meet the soil in question. Whichever order’s criteria aligns best with the soil in question first will be the soil order selected. This process is used for all subsequent categories in the ordering of order, suborder, great group, and subgroup. Family and Series are determined by other individual methods using criteria outlined in the *Keys to Soil Taxonomy* (2014).

### Order

There are 12 soil orders in total (Table 4). The geographical range of each order is dependent upon several environmental processes and climatic factors (i.e. temperature, precipitation, etc.) leading to soil formation. Soil order is the first to be determined when classifying a soil.

Table 4. “Simplified key to the 12 soil orders” by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0 The bolded syllable in each order is the formative element used in the names of suborders and lower taxonomic levels.

| Order | Major Diagnostic Features |
|---|---|
| Ge**li**sols | Soils with permafrost or gelic material within 100 cm |
| Hi**st**osols | Other soils with >30% organic matter (>12% organic carbon) content to a depth of 40 cm or more |
| Sp**od**osols | Other soils with a spodic horizon (illuvial humus, iron) within a depth of 200 cm |
| **And**isols | Other soils with andic soil properties (low density, volcanic glass, pumice, etc.) in ≥50% of the upper 60 cm |
| **Ox**isols | Other soils with an oxic horizon, or containing more than 40% clay in the surface 18 cm and a kandic horizon with less than 10% weatherable minerals (highly weathered) |
| V**ert**isols | Other soils containing more than 30% clay in all horizons and cracks that open and close periodically (shrinking/swelling) |
| Ar**id**isols | Other soils with some diagnostic subsoil horizon(s) and an aridic soil moisture regime |
| **Ult**isols | Other soils with an argillic or kandic horizon and a base saturation at pH 8.2 of <35% at a depth of 180 cm |
| M**oll**isols | Other soils with a Mollic epipedon and a base saturation at pH 7 of ≥50% in all depths above 180 cm |
| **Alf**isols | Other soils with an argillic, kandic, or natric horizon (and a base saturation at pH 8.2 of >35% at a depth of 180 cm) |
| Inc**ept**isols | Other soils with an umbric, mollic, or plaggen epipedon or a cambic horizon |
| **Ent**isols | Other soils |

## Suborder

Soil suborders are determined based on soil moisture regimes and diagnostic features. Formative elements specify unique soil properties at each taxonomic level and has a connotation for a given soil.

The formative elements for suborder are listed in, (Table 5).

Table 5. "Formative elements used to identify various suborders in Soil Taxonomy" by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

| Formative element | Connotation | Formative element | Connotation |
|---|---|---|---|
| alb | Presence of albic horizon (a bleached eluvial horizon) | hist | Presence of histic epipedon |
| anthr | Presence of anthropic or plaggen epipedon | hum | Presence of organic matter |
| aqu | Characteristics associated with wetness | orth | The common ones |
| ar | Mixed horizons | per | Of year-round humid climates, perudic moisture regime |
| arg | Presence of argillic horizon (a horizon with illuvial clay) | psamm | Sand textures |
| calc | Presence of calcic horizon | rend | Rendzinalike-high in carbonates |
| camb | Presence of cambric horizon | sal | Presence of salic (saline) horizon |
| cry | Cold | sapr | Most decomposed stage |
| dur | Presence of a duripan | torr | Usually dry |
| fibr | Least decomposed stage | turb | Cryoturbation |
| fluv | Floodplains | ud | Of humid climates |
| fol | Mass of leaves | ust | Of dry climates, usually hot in summer |
| gyps | Presence of gypsic horizon | vitr | Resembling glass |
| hem | Intermediate stage of decomposition | xer | Dry summers, moist winters |

## Great group

The great group expresses the degree of diagnostic horizon expression within each suborder taxa. The formative elements for great group are listed in (Table 6).

Table 6. “Formative elements for names of great groups and their connotations” by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

| Formative element | Connotation | Formative element | Connotation |
|---|---|---|---|
| acr | Extreme weathering | hist | Presence of organic materials |
| aer | Chroma >2, non-reducing | fragi | Fragipan |
| agr | Agric horizon | hum | Humus |
| al | High aluminum, low iron | hydr | Water |
| alb | Albic horizon | kand | Low-activity 1:1 silicate clay |
| and | Ando-like | lithic | Near stone |
| anhy | Anhydrous | luv, lu | Illuvial |
| aqu | Water saturated | melan | Melanic epipedon |
| aren | Sandy | molli | With a mollic epipedon |
| argi | Argillic horizon | natr | Presence of a natric horizon |
| calc, calci | Calcic horizon | pale | Old development |
| camb | Cambic horizon | petr | Cemented horizon |
| chrom | High chroma | plac | Thin pan |
| cry | Cold | plagg | Plaggen horizon |
| dur | Duripan | plinth | Plinthite |
| dystr, dys | Low base saturation | psamm | Sand texture |
| endo | Fully water saturated | quartz, quartzi | High quartz |
| epi | Perched water table | rhod | Dark red colors |
| eutr | High base saturation | sal | Salic horizon |
| ferr | Iron | sapr | Most decomposed |
| fibr | Least decomposed | somb | Dark horizon |
| fluv | Floodplain | sphagn | Sphagnum moss |
| fol | Mass of leaves | sulf | Sulfur |
| fragloss | See frag and gloss | torr | Usually dry and hot |
| fulv | light-colored melanic horizon | ud | Humid climates |
| gyps | Gypsic horizon | umbr | Umbric epipedon |
| gloss | Tongued | ust | Dry climate, usually hot in summer |
| hal | Salty | verm | Wormy, or mixed by animals |
| hapl | Minimum horizon | vitr | Glass |
| hem | Intermediate decomposition | xer | Dry summers, moist winters |

## Subgroup

A soil's subgroup is defined by properties that are transitional or similar to those found in other orders, suborders, and great groups.

## Family

The family is typically comprised of more than one component that is determined for the soil in question using information detailed in chapter 17 of the *Keys to Soil taxonomy*. The technical family name is comprised of descriptive terms for family information such as, particle size class and mineralogy of control section, soil temperature regime, CEC, depth, rupture-resistance, etc.

## Complete taxonomical name

After each category is subsequently determined by the systematical methods of the Keys to Soil Taxonomy, a complete taxonomic name is the end result (Figure2). A complete taxonomic name communicates a great deal of information about the soil if we understand each part of the name (Table 8).

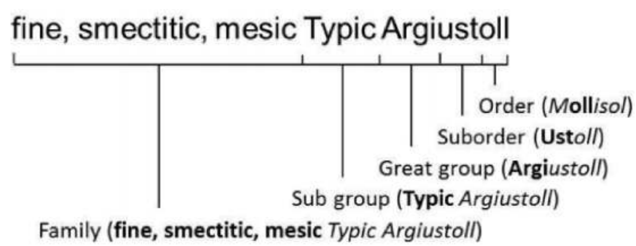



Figure 2. "Formative elements in the taxonomic classification of the Harney series" by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

Table 8. "Translation of the taxonomic classification of the Harney Series" by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

| Categories | Properties connoted |
|---|---|
| ORDER: Mollisol | Has a mollic epipedon and a base saturation of >50% to a depth of 1.8 m from the soil surface or to an impermeable layer |
| SUBORDER: Ustoll | has an ustic moisture regime; dry for as long as 90 days cumulatively per year |
| GREAT GROUP: Argiustoll | has an argillic horizon |
| SUBGROUP: Typic Argiustoll | typical of an Argiustoll, not intergrading toward another great group condition |
| FAMILY: fine, smectitic, mesic | the upper 50 cm of the argillic horizon has 35-60% clay; the dominant clay minerals are smectite minerals (montmorillonite, beidellite, and nontronite); the mean annual soil temperature at 50 cm is 8°C to 15°C (47°F to 59°F) |
| SERIES: Harney | differs from soils in the same family in based on color, parent material (loess), and calcium accumulation below 28 in. |

# 3.2: Pre-Class Activity- Classified Location Exercise

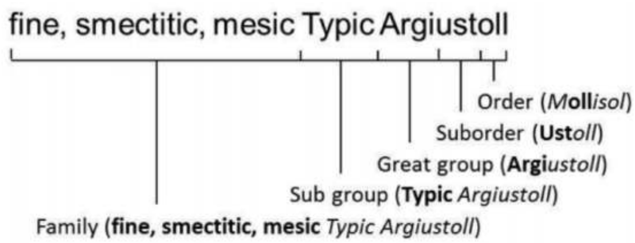
Name: ______________________________

Section: _____________________________

Student ID#:__________________________

To help familiarize ourselves with some basics of Soil Taxonomy we will parallel some of the unfamiliar concepts of the taxonomical system of soil with the familiar concepts of where you are from, or another special place of your choice! So let's take this step by step…

*To begin, this is what a classified soil looks like in text:*




To break things down, each soil taxonomical category is described in general detail below, outlining what information contributes to each of the categories:

| Taxonomical category | Description of defining/diagnostic information | Example |
|---|---|---|
| Order | One of the 12 soil orders* | Alfisol, Gelisol, Oxisol |
| Suborder | Soil moisture regimes and diagnostic horizons | **Aqu**alf- **Wet** Alfisol<br>**Fluv**ent- Entisol **on floodplain** |
| Great group | Degree of diagnostic horizon expression within each suborder taxa | **Cry**aqualfs- **cold**, wet, Alfisol<br>**Fragi**aqualfs- **have fragipans** and are wet Alfisols |
| Subgroup | Properties that are transitional or similar to those found in other orders, suborders, and great groups | **Humic** Fragiaualfs- **presence of organic matter** in a wet Alfisol with fragipan |
| Family | Particle size class and mineralogy of the control section, soil temperature regime, CEC, depth, ruptureresistance, etc. | **Fine, smectic, mesic**<br>**Mixed, mesic** |
| Series | Any consistently identifiable soil property not specifically identified as criteria in a higher category | **Forkwood**<br>**Narragansett**<br>**Hoosic** |

*The 12 Soil Orders: (Alfisol, Andisol, Aridisol, Entisol, Gelisol, Histosol, Inceptisol, Mollisol, Oxisol, Spodosol, Ultisol, Vertisol)

**Now, let's relate similar taxonomical concepts to information and details regarding your hometown, or favorite place…**

## ORDER:

Order is the broadest of the categories, while still providing a sense of overall identity. Please select one of the following states or territories that is most applicable to the location of your hometown/favorite place. If located outside the US, please note it as, “OUS” (outside U.S.). Your classification text should be as follows: ______, ______, ______, ______ ____ ____ HI

| | |
|---|---|
| Alabama - AL | New Mexico - NM |
| Alaska - AK | New York - NY |
| Arizona - AZ | North Carolina - NC |
| Arkansas - AR | North Dakota - ND |
| California - CA | Ohio - OH |
| Colorado - CO | Oklahoma - OK |
| Connecticut - CT | Oregon - OR |
| Delaware - DE | Pennsylvania - PA |
| Florida - FL | Rhode Island - RI |
| Georgia - GA | South Carolina - SC |
| Hawaii - HI | South Dakota - SD |
| Idaho - ID | Tennessee - TN |
| Illinois - IL | Texas - TX |
| Indiana - IN | Utah - UT |
| Iowa - IA | Vermont - VT |
| Kansas - KS | Virginia - VA |
| Kentucky - KY | Washington - WA |
| Louisiana - LA | West Virginia - WV |
| Maine - ME | Wisconsin - WI |
| Maryland - MD | Wyoming - WY |
| Massachusetts - MA | American Samoa - AS |
| Michigan - MI | District of Columbia - DC |
| Minnesota - MN | Federated States of Micronesia - FM |
| Mississippi - MS | Guam - GU |
| Missouri - MO | Marshall Islands - MH |
| Montana - MT | Northern Mariana Islands - MP |
| Nebraska - NE | Palau - PW |
| Nevada - NV | Puerto Rico - PR |
| New Hampshire - NH | Virgin Islands - VI |
| New Jersey - NJ | |

## Suborder:

This describes one of the most defining characteristics of your hometown, whether that be proximity to the coast, overall moisture conditions, elevation, etc. For example, : If I live in Hawaii, my most defining feature is that I live on an Island, so I will designate this as…

______, ______, ______, ______ ___ islhi

isl= on an island, hi= in Hawaii

*Please select one of the following below that best describes your location:*

| | |
|---|---|
| **Anthr**- located in a city with a lot of human activity and impact | **Hi**- located at an elevation higher than 5K ft |
| **Aqu**- impacted by a lot of rain | **Inl**- located inland |
| **Coas**- located on or near the coast (~15 mi) | **Isl**- located on an island |
| **Cry**- cold most of the year | **Lo**- located at an elevation lower than 1K ft |
| **Des**- located in the desert | **Sno**- impacted by a lot of snow |
| **Dry**- dry land conditions | **Riv**- located near a prominent river or freshwater body |
| **For**- live in a forest | **War**- warm/hot most of the year |
| **Emp**- vast lands | |

## Great group:

This describes your location further in depth, almost like an adjective to describe the prominent feature of your locale. For example: If I live in Hawaii, I will first say I live on an Island, and on this Island I live extremely close to the coast (<15 mi), so I will designate this as…

______, ______, ______, ______ Coasislhi

Coas = on the coast, isl= on an island, hi= in Hawaii

*Please select one of the following great group descriptions below to further detail your location:*

| | |
|---|---|
| **Anthr**- located in a city with a lot of human activity and impact | **Lo**- located at an elevation lower than 1K ft |
| **Aqu**- impacted by a lot of rain | **Mou**- live on a mountain |
| **Coas**- located on or near the coast (~15 mi) | **Sno**- impacted by a lot of snow |
| **Cry**- cold most of the year | **Sun**- extreme exposure to sun |
| **Des**- located in the desert | **Ran**- live on a ranch or farm |
| **Dry**- dry land conditions | **Riv**- located near a prominent river or freshwater body |
| **Emp**- vast lands | **Roa**- live near a major highway or road |
| **For**- live in a forest | **Wet**- live very close to a wetland |
| **Hi**- located at an elevation higher than 5K ft | **War**- warm/hot most of the year |
| **Inl**- located inland | **Woo**- wooded area with a high presence of vegetation |
| **Isl**- located on an island | |

## Subgroup:

This category will detail the most defining and unique element of your location, that sets it apart from the rest of town. Consider any of the following below, however, we encourage you to come up with your most defining feature that comes to mind when you think of the landscape of your location. For example: If I live in Lousiana, I will first say I live in a warm/hot location, located near the coast, and in a wetland- so, I will designate this as…

______, ______, ______, __Wetty Coaswarla

*Please select one of the following subgroup descriptions below to further detail your location:*

| | |
|---|---|
| **Anthro**- located in a city with a lot of human activity and impact | **Mounty**- live on a mountain |
| **Aquic**- receives a lot of rain | **Snowy**- impacted by a lot of snow |
| **Coasty**- coastal conditions (~15 mi) | **Sunny**- extreme exposure to sun |
| **Cryic**- cold most of the year | **Ranchy**- live on a ranch or farm |
| **Deserty**- desert conditions | **Rivery**- located near a prominent river or freshwater body |
| **Dryish**- dry land conditions | **Roady**- live near a major highway or road |
| **Empty**- vast lands | **Typic**- very typical location for the state it is located in |
| **Foresty**- live in a forest | **Wetty**- live very close to a wetland |

| | |
|---|---|
| **Highly**- located at an elevation higher than 5K ft | **Warmish**- warm/hot most of the year |
| **Inner**- located inland | **Woodsy**- wooded area with a high presence of vegetation |
| **Lower**- located at an elevation lower than 1K ft | |

## Family:

This is where you can get creative! Provide three additional details about your location that people may not gather about this place, unless they have visited. Please keep each detail to one word or a hyphenated phrase. For example: if I took the previous example a step further, assuming I live in New Orleans, LA, it would look something like this:

spicy, jazzy, humid, Wetty Coaswarla

*Here are some guidelines to use for family details:*

**Detail 1**- something to describe the local cuisine/food

**Detail 2**- something to describe the local art, music, or recreation scene

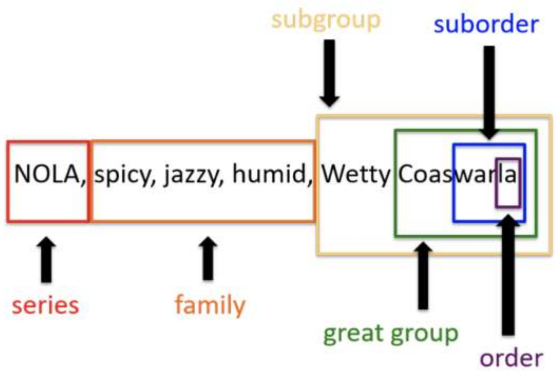
**Detail 3**- something to describe the local weather

**Series:** Finally, your series name should be the name of your town or a fun nickname the locals give it.

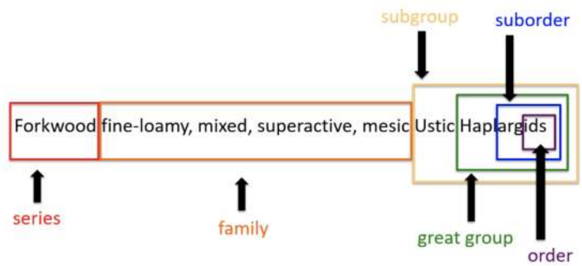
For example: Again, if I was talking about New Orleans, LA, I would call it the “NOLA” series.

(If using a nickname, please make them all school appropriate)

This now brings us to our final classified location, described as:




And when we compare our classified location to a similarly classified soil, it looks something like this:




### WHAT IS THE NAME OF YOUR FINAL CLASSIFIED LOCATION?

_____________ ____________, _____________, ______________, _________ _____________

*DISCUSSION*: In groups of 2-3, share your full classification name and discuss how your location compares to you peers'. Do you see some similarities? Differences? Do you think each location is described accurately?

### TEMPERATURE AND MOISTURE REGIMES

Temperature and moisture play a critical role in soil formation and the morphological expression of soil. More importantly, specified temperature and moisture regimes are used to determine specific portions of the classification of a soil (i.e. suborder, family).

## Temperature regimes:

| | |
|---|---|
| Gelic: < 0°C | Mesic: 8-15°C |
| Cryic: 0-8°C (cold summers) | Thermic: 15-22°C |
| Frigid: 0-8°C (warm summers) | Hyperthermic: >22°C |

### Moisture regimes:

| |
|---|
| Aquic: (or Perudic): Saturated with water long enough to cause oxygen depletion |
| Udic: Humid or subhumid climate |
| Ustic: Semiarid climate |
| Aridic (or Torric): Arid climate |
| Xeric: Mediterranean climate (cool, moist winters and warm, dry summers) |

## HORIZONS AND CHARACTERISTICS DIAGNOSTIC FOR THE HIGHER CATEGORIES

Soil classification is determined by the detailed morphology described for each soil. From the morphology we can then determine horizons and characteristics that are indicative, or diagnostic, for higher categories of soil classification. This section is split up into three categories critical for soil classification within the Keys to Soil Taxonomy: 1) Diagnostic surface horizons, 2) Diagnostic subsurface horizons, and 3) Diagnostic characteristics.

### Diagnostic surface horizons- Epipedons

The epipedon is a horizon that forms at or near the surface, to which a majority of the rock structure has been destroyed. This layer is typically darkened from organic inputs, shows eluviation, or both (refer to the Keys to Soil Taxonomy for further details). Important epipedons are outlined in detail below in, Table 2.

Table 2. Epipedons described by major defining features (Adapted from SOIL 2010 lecture: Vaughan, 2018).

| Epipedon | Major Features |
|---|---|
| Mollic | Thick, organic-rich layer common in grasslands and is diagnostic for Mollisols. High base saturation. |
| Umbric | Acidic, similar to Mollic except less fertile with low base saturation |
| Histic | Dark, organic surface layer (not mineral soil). Typically formed in wet areas with low bulk density. |
| Mellanic | Organic-rich, volcanic surface layer. |
| Ochric | Low organic matter, light-colored, diagnostic for Aridisols. |

### Diagnostic subsurface horizons- Endopedons

Soils described in this section specifically form below the surface of the soil, however, in some areas they form directly below layer of a leaf litter if no epipedon is present. These horizons are comprised of mineral material and are generally identified as B horizons, or parts of A or E horizons. The most common endopedons are detailed below, in Table 3.

Table 3. Endopedons described by major defining features (Adapted from SOIL 2010 lecture: Vaughan, 2018).

| Endopedon | Major features |
|---|---|
| Argillic (Bt) | High activity clay accumulation AND clay films present, common in mature soils of temperate regions. Diagnostic for Alfisols. |
| Oxic (Bo) | Highly weathered, usually reddish due to abundance of Fe oxides. Associated with Oxisols. |
| Spodic (Bh, Bs, Bhs) | Organic matter and/or Fe-Al oxides. |
| Albic (E) | Light colored where clays and organic matter have been removed by eluvial processes. |
| Cambic (Bw) | Changes in color or structure from A. Some horizon development. Diagnostic for Inceptisols. |
| Calcic (Bk) | Accumulation of $CaCO_3$ (calcite) or CaMg $(CO_3)_2$ (dolomite). |
| Petrocalcic (Bkm) | Cemented calcic horizon. |
| Duripan (Bqm) | Silica cemented horizon. |

### Diagnostic soil characteristics

Diagnostic soil characteristics are specific soil features used throughout the Keys to Soil Taxonomy, and more importantly, used to define specific diagnostic horizons. Important diagnostic soil characteristics are listed below, and further details are outlined in the full-text version of *Keys to soil Taxonomy.*

| | |
|---|---|
| • Abrupt textural change<br>• Albic materials<br>• Andic soil properties<br>• Fragic soil properties<br>• Free carbonates<br>• Identifiable secondary carbonates<br>• Lithologic discontinuity<br>• Slickensides<br>• Spodic materials<br>• Volcanic glass | • Aquic conditions<br>• Cryoturbation<br>• Densic contact<br>• Gelic materials<br>• Lithic contact<br>• Paralithic contact<br>• Paralithic materials<br>• Permafrost<br>• Soil moisture regimes<br>• Soil temperature regimes |

# 3.3: Activity 1- Horizons and Characteristics

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

Your instructor has placed out soil descriptions for the Wycolo the Passcreek soil series, both located in Wyoming. Using the information provided, please answer the following questions:

*1) What is the epipedon of…*

*a. Wycolo?*

*b. Passcreek?*

*2) What is the endopedon(s) of…*

*a. Wycolo?*

*What details/soil properties helped you come to this conclusion? (Please list)*

*b. Passcreek?*

*What details/soil properties helped you come to this conclusion? (Please list)*

*3) Please identify the temperature and moisture regimes for the following soils…*

*Wycolo T.R. = Passcreek T.R. =*

*Wycolo M.R. = Passcreek M.R. =*

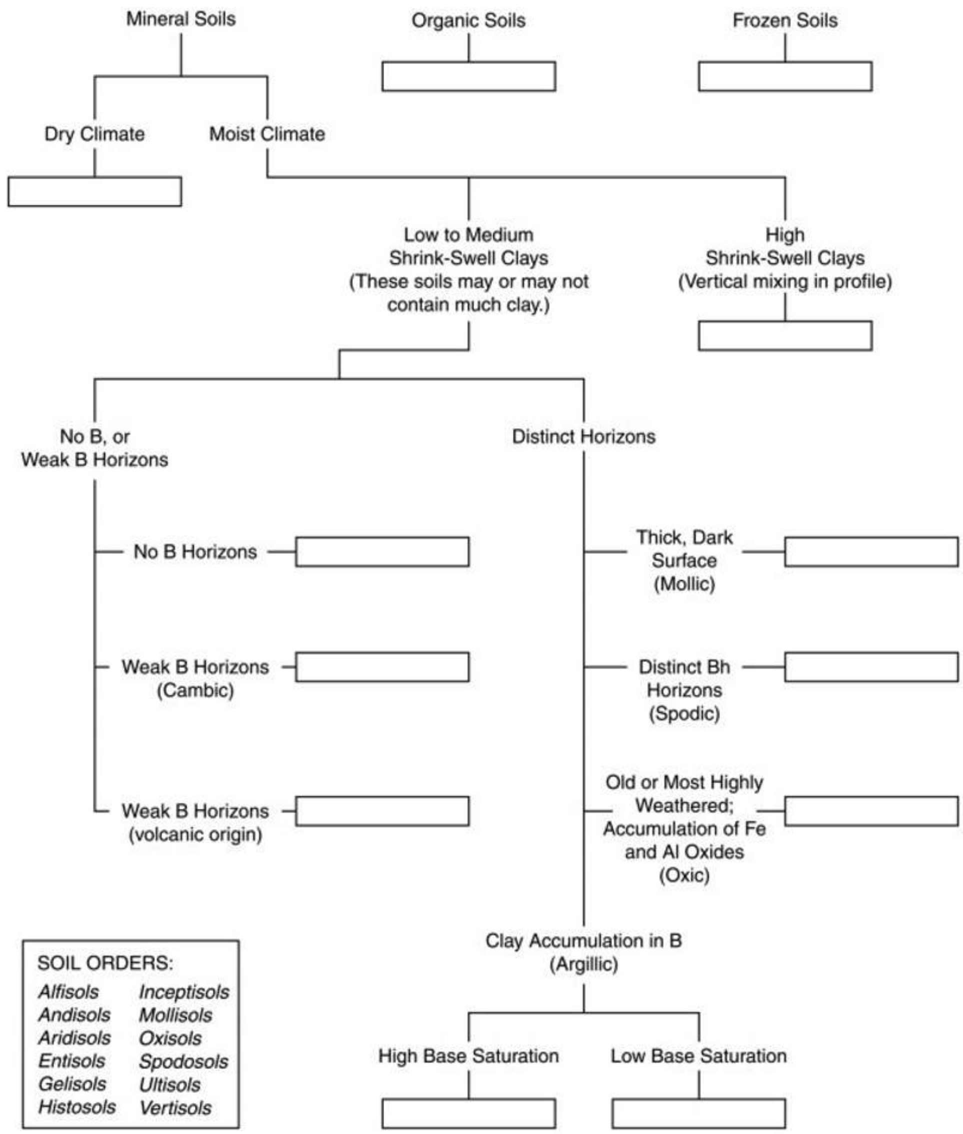
# 3.4: Activity 2 - Taxonomic Class

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

1) *Now that you have studied the characteristics of the 12 soil orders, enter the most appropriate soil order name in each rectangle:*




2) *To illustrate the structure of Soil Taxonomy, separate a complete taxonomic name into the 6 categories. Follow the example of the Harney silt loam earlier in this laboratory.*

*a) Colby:*

*a. Taxonomic Name: Fine-silty, mixed, superactive, calcareous, mesic Aridic Ustorthents*

*b. Order-*

*c. Suborder-*

*d. Great Group-*

*e. Subgroup-*

*f. Family-*

*g. Series-*

*b) Goessel:*

*a. Taxonomic Name: Fine, smectitic, mesic Typic Haplusterts*

*b. Order-*

*c. Suborder-*

*d. Great Group-*

*e. Subgroup-*

*f. Family-*

*g. Series-*

*c) Wymore:*

*a. Taxonomic Name: Fine, smectitic, mesic Aquertic Argiudolls*

*b. Order-*

*c. Suborder-*

*d. Great Group-*

*e. Subgroup-*

*f. Family-*

*g. Series-*

*3) State soils have been selected for all 50 states and three territories in the U.S. The group of soils represents a diverse sample of soil conditions and classifications. It serves as an interesting focus for a little practice at deciphering and understanding Soil Taxonomy. Use the attached list of state soils in Table 9 to reference state soil information. Tables 4, 5, and 6 will also help you with this exercise.*

*a) What is the most commonly recognized ORDER among the state soils?*

*b) Which of the soil ORDERS is not represented in the list of state soils?*

*c) How many Oxisols are represented by the 53 soils?*

*d) What is the complete SUBORDER name for the state soil of Alaska?*

*e) How many Vertisols are represented in the state soils?*

*f) In what soil property does the Downer soils of New Jersey differ from the Greenwich soils of Delaware?*

*g) The state soil of South Carolina has a soil condition identified by its great group. What element is present in the upper 50 cm of this soil? (Hint: use Table 6)*

*h) What is the complete taxonomic name for the state soil of Wyoming?*

Table 9. "Soil Taxonomy classifications of state soils of the U.S." by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

| SERIES | STATE | FAMILY CLASSIFICATION |
|---|---|---|
| Tanana | AK | coarse-loamy, mixed, superactive, subgelic Typic Aquiturbels |
| Bama | AL | fine-loamy, siliceous, subactive, thermic Typic Paleudults |
| Stuttgart | AR | fine, smectitic, thermic Albaquultic Hapludalfs |
| Casa Grande | AZ | fine-loamy, mixed, superactive, hyperthermic Typic Natrargids |
| San Joaquin | CA | fine, mixed, active, thermic Abruptic Durixeralfs |
| Seitz | CO | clayey-skeletal, smectitic Ustic Glossocryalfs |
| Windsor | CT | mixed, mesic Typic Udipsamments |
| Greenwich | DE | coarse-loamy, mixed, semiactive, mesic Typic Hapludults |
| Myakka | FL | sandy, siliceous, hyperthermic Aeric Alaquods |
| Tifton | GA | fine-loamy, kaolinitic, thermic Plinthic Kandiudults |
| Akina | GU | very-fine, kaolinitic, isohyperthermic Inceptic Haplustox |
| Hilo | HI | medial over hydrous, ferrihydritic, isohyperthermic Acrudoxic Hydrudands |
| Tama | IA | fine-silty, mixed, superactive, mesic Typic Argiudolls |
| Threebear | ID | medial over loamy, amorphic over mixed, superactive, frigid Oxyaquic Udivitrands |
| Drummer | IL | fine-silty, mixed, superactive, mesic Typic Endoaquolls |
| Miami | IN | fine-loamy, mixed, active, mesic Oxyaquic Hapludalfs |
| Harney | KS | fine, smectitic, mesic Typic Argiustolls |
| Crider | KY | fine-silty, mixed, active, mesic Typic Paleudalfs |
| Ruston | LA | fine-loamy, siliceous, semiactive, thermic Typic Paleudults |
| Paxton | MA | coarse-loamy, mixed, active, mesic Oxyaquic Dystrudepts |
| Sassafras | MD | fine-loamy, siliceous, semiactive, mesic Typic Hapludults |
| Chesuncook | ME | coarse-loamy, isotic, frigid Aquic Haplorthods |
| Kalkaska | MI | sandy, isotic, frigid Typic Haplorthods |
| Lester | MN | fine-loamy, mixed, superactive, mesic Mollic Hapludalfs |
| Menfro | MO | fine-silty, mixed, superactive, mesic Typic Hapludalfs |
| Natchez | MS | coarse-silty, mixed, superactive, thermic Typic Eutrudepts |
| Scobey | MT | fine, smectitic, frigid Aridic Argiustolls |
| Cecil | NC | fine, kaolinitic, thermic Typic Kanhapludults |
| Williams | ND | fine-loamy, mixed, superactive, frigid Typic Argiustolls |

| SERIES | STATE | FAMILY CLASSIFICATION |
|---|---|---|
| Holdrege | NE | fine-silty, mixed, superactive, mesic Typic Argiustolls |
| Marlow | NH | coarse-loamy, isotic, frigid Oxyaquic Haplorthods |
| Downer | NJ | coarse-loamy, siliceous, semiactive, mesic Typic Hapludults |
| Penistaja | NM | fine-loamy, mixed, superactive, mesic Ustic Haplargids |
| Orovada | NV | coarse-loamy, mixed, superactive, mesic Durinodic Xeric Haplocambids |
| Honeoye | NY | fine-loamy, mixed, semiactive, mesic Glossic Hapludalfs |
| Miamian | OH | fine, mixed, active, mesic Oxyaquic Hapludalfs |
| Port | OR | fine-silty, mixed, superactive, thermic Cumulic Haplustolls |
| Hazleton | PA | loamy-skeletal, siliceous, active, mesic Typic Dystrudepts |
| Bayamon | PR | very-fine, kaolinitic, isohyperthermic Typic Hapludox |
| Narragansett | RI | coarse-loamy over sandy or sandy-skeletal, mixed, active, mesic Typic Dystrudepts |
| Bohicket | SC | fine, mixed, superactive, nonacid, thermic Typic Sulfaquents |
| Houdek | SD | fine-loamy, mixed, superactive, mesic Typic Argiustolls |
| Dickson | TN | fine-silty, siliceous, semiactive, thermic Glossic Fragiudults |
| Houston Black | TX | fine, smectitic, thermic Udic Haplusterts |
| Taylorsflat | UT | fine-loamy, mixed, superactive, mesic Xeric Haplocalcids |
| Pamunkey | VA | fine-loamy, mixed, semiactive, thermic Ultic Hapludalfs |
| Victory | VI | loamy-skeletal, mixed, superactive, isohyperthermic Typic Haplustepts |
| Tunbridge | VT | coarse-loamy, isotic, frigid Typic Haplorthods |
| Tokul | WA | medial, amorphic, mesic Aquic Vitrixerands |
| Antigo | WI | coarse-loamy over sandy or sandy-skeletal, mixed, superactive, frigid Haplic Glossudalfs |
| Monongahela | WV | fine-loamy, mixed, semiactive, mesic Typic Fragiudults |
| Forkwood | WY | fine-loamy, mixed, superactive, mesic Ustic Haplargids |

LibreTexts

# CHAPTER OVERVIEW

## 4: Soil Survey and Mapping

**Learning Objectives**

- To be able to obtain soil survey data.
- To become familiar with the information provided in a soil survey report.
- To learn how to evaluate the suitability of soils for both agricultural and non-agricultural uses.
- To navigate Web Soil Survey and generate a custom soil survey report.

**GOAL**: To become familiar with and learn how to use soil survey data



**Additional resources**:

- The following web site can be accessed to obtain the official series description for specific soil series: http://soils.usda.gov/ and https://soilseries.sc.egov.usda.gov/osdname.aspx
- Video link: Using the Web Soil Survey Tool https://youtu.be/fzpKPIJajdQ

# 4.1: Introduction- Soil Survey Reports

The properties of each soil must be understood to ensure proper use and management. To consider the soil in land use planning and development, an inventory is essential in determining the location and extent of the various kinds of soil. This inventory is called a soil survey.

Soil surveys began in 1898 in the United States. The study of soils was initially conducted for agriculture and forestry, with little attention given to the ways in which soil properties might influence urban use of land. Modern soil surveys now include information about multipurpose uses of soils. These include interpretation information for wildlife management, development of parks and recreation areas, construction potentials for super highways, airports, and building foundations, selection of pipeline right-of-ways, evaluation of the pollution potential from septic tanks, selection of desirable spatial distribution patterns for residential, commercial, industrial, agricultural, and recreational land use development, implementation of zoning and subdivision control, and land evaluation for equitable tax assessments and bank loan appraisals.

# 4.2: What is a soil survey?

A soil survey is a detailed inventory of the soil resources within an area. It consists of a set of soil maps and a book that describes, classifies, and interpret soil data for various land uses. It is developed by professional soil scientists who examine the soil in detail to a depth of two meters, or to rock if shallower. The soil is then classified according to a national system of soil taxonomy. The location of each kind of soil is plotted on aerial photographs. Each soil is evaluated for its suitability for various uses and management.

Soil surveys are made in the following manner: air photo reconnaissance flights are made of the area to obtain stereoscopic map photos. These photos permit one to see artificial and natural land features. In preparing a soil survey, the scientists familiarize themselves with the various soils in the area by digging many holes to expose and carefully examine the soil profile in its natural state. As they travel around the survey area, they observe steepness, the length and shape of slopes, the size and speed of streams, the kinds of trees, plants and crops, the kinds of rock exposed, and many facts about the soils.

Soil scientists compare the soil profiles in the survey area with soils in nearby counties and states. They correlate, classify and name the different soils according to the National Cooperative Soil Survey as set forth in the United States Department of Agriculture (USDA) Agricultural Handbook No. 18, Soil Survey Manual (August, 1951). Details of the classification are presented in the book Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys written by the Soil Survey Staff of the Soil Conservation Service (now the Natural Resource Conservation Service). It was published in December of 1975 as USDA Agricultural Handbook No. 436.

Once the soils have been named and their distinguishing properties identified, the soil scientists return to the field to examine all soils in the survey area. They delineate areas of similar soils directly on the aerial photographs. While the field work is in progress, other soil samples are collected and analyzed to determine chemical, physical, and mineralogical properties. The mass of detailed information about the soils needs to be organized and interpreted in a readily useful way to different groups of readers.

For many years, farmers and ranchers have used soil surveys to determine the capability of the soil to support certain kinds of crops, grasses, and trees. Also, soil surveys have served as a basis for applying needed soil and water conservation practices.

After studying the soils in an area, it is possible to make a general map showing several main patterns of soils (called soil associations). As a rule, each soil association contains a few major soils and several minor soils in a characteristic, although not strictly uniform, pattern. The soil maps are assembled and examined for continuity of soil boundaries from one photo to another and the other information is compiled into a written report.

The written report and the aerial photographs with the soil boundaries are sent to the U.S. Government Printing Office for publication. This entire process of obtaining aerial photos, field mapping, correlation and interpretation of the data, writing of the report, and subsequent publication takes several years for completion.

Soil surveys produced in this manner cost taxpayers $500 to $750 per square mile. Large expanses of land that are of little direct value for agricultural or forest uses often are too poor to justify this high cost. These low value areas are mapped on a small scale and the resulting study is called a reconnaissance survey. The reconnaissance survey identifies areas and regions dominated by soil associations in contrast to the detailed map where specific soils are delineated.

# 4.3: Challenges in soil surveying

Several problems unique to the field work and mapping occur in soil surveys. Because soil series vary so much in slope, degree of erosion, number and size of stones, or some other feature affecting their use, practical suggestions about their management could not be made if they were shown on the soil map as one unit. Such soil series are divided into soil phases. The name of the soil phase indicates the surface feature most affecting its management. For example, Vina loam, 0 to 2 percent slopes; Vina loam, 2 to 9 percent slopes; Vina gravelly loam, 2 to 9 percent slopes; and Vina silty clay loam, 2 to 9 percent slopes are four soil phases of the Vina series.

The area enclosed within each continuous line on a soil map is the delineation of a map unit. The map unit includes the soil phase and all inclusions. A problem for the soil scientist arises in delineating areas where several different soils are so intricately associated and so small in size it is not practical to show them separately on the aerial photo maps. Therefore, they show this conglomerate of soils as one mapping unit and call it a soil complex.

Ordinarily, a soil complex is named for the major kinds of soils in it. For example, *Castaic-Balcom complex, 9 to 15 percent slopes, eroded and Millsholm-Malibu complex, 30 to 50 percent slopes, eroded* occur in the Ventura Area Soil Survey.

Another problem occurs when the soils have been disturbed by road work and other mining or construction activities to such an extent the original characteristics of the soil have been obliterated. These areas are delineated on the soil map as are other map units by being called "made land", "pits and dumps", and "fill land". Other natural non-soil areas are given descriptive names such as: "badland", "igneous rock land", "landslides", "sandy alluvial land", and "terrace escarpments".

# 4.4: Responsibility for soil surveys

The Natural Resource Conservation Service (formerly the Soil Conservation Service) of the USDA has the primary authority and responsibility for soil surveys. In some areas, the Forest Service, the Bureau of Indian Affairs, the Bureau of Reclamation, or the Bureau of Land Management conduct surveys of lands within their jurisdictions. Other state agencies such as departments of natural resources or conservation and the county or city governments may cooperate. This joint effort is called the National Cooperative Soil Survey.

The United States Department of Agriculture Natural Resource Conservation Service (USDA NRCS) today provides these soil surveys in a digital format through the Web Soil Survey (United States Department of Agriculture Natural Resources Conservation Service, 2016). The Web Soil Survey provides all the information previously contained in the county soil survey reports. It also contains additional tools and information that has not been available in printed versions of the soil surveys. Another advantage of the Web Soil Survey is that the information contained in it can be updated as needed, instead of being updated following new surveys of the same county, which take 30 to 60 years! Your instructor will walk you through some of the main features of the Web Soil Survey and show you how to request a PDF copy of a soil survey report for a designated area. You will use these skills for your Soil Survey Report assignment.

*Read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

# 4.5: Activity 1 - Using Web Soil Survey

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

*Read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

Video link: Using the Web Soil Survey Tool https://youtu.be/fzpKPIJajdQ

To begin this project, go to http://websoilsurvey.nrcs.usda.gov/app/.

- Read Welcome to Web Soil Survey and Three Basic Steps.
- Click on the green START WSS icon.
- You will be choosing an Area of Interest (AOIs) following the instructions on the web site.
  - Your AOI can be anywhere in the United States where soil survey information is available.
  - For purposes of this assignment, your AOI should be approximately 1000-2000 acres in size.

1. In what state(s) is your AOI located? _____________________

## SOIL MAP UNITS

2. For the AOI you have selected, go to the Soil Map tab (located near top of page) to generate a map showing the AOI and its component soil map units. Save a PDF this map of your AOI and attach it to this report.

*Generate the soil map report for your AOI (go to the "shopping cart" and generate a pdf). Include this pdf as part of your final assignment submission with the subject line "LAST NAME WSS lab."*

3. Choose a particular point location on each of the maps – this can be a house, school, part of a ranch, etc.

4. Determine which soil map unit contains the selected point.

map unit symbol:

map unit name:

What percentage of the AOI does this map unit occupy?

Which soil series makes up most of this map unit?

## SOIL DATA EXPLORER

Next, you will examine information about soil properties and land-use interpretations for your map units. Answer questions 5-12 for the chosen map unit from your AOI.

Go to the **Soil Data Explorer** tab and then select the tab heading entitled *Soil Properties and Qualities.*

5. Select *Water Features* and determine *Depth to Water Table* for your map unit. Do this by clicking on the *View Rating* button. You can use all of the default settings.

Depth to water table = _____________ (include units)

6. Next, select *Soil Physical Properties*.

What is the *Surface Texture* for your map unit? _______________________

Find the *Bulk Density (One-Third Bar)* for the surface layer of your map unit (you will have to use *Advanced Options* > *Layer Options* > *Surface Layer* to get information for the surface layer).

Surface layer bulk density = ______________

7. Now select *Soil Chemical Properties*. Find the *pH (1 to 1 water)* for the surface soil layer of your map unit (you will have to use *Advanced Options* > *Layer Options* > *Surface Layer* to get information for the surface layer).

Surface layer pH = __________

8. Now select *Soil Qualities and Features*. Find the *Depth to Any Soil Restrictive Layer* for your map unit (default settings are OK).

Depth to any soil restrictive layer = ____________

Soil depth class = ____________________

| Depth Class | Soil Depth (cm) |
|---|---|
| Very shallow | 0-20 |
| Shallow | 20-50 |
| Moderately deep or Moderately Shallow | 50-100 |
| Deep | 100-150 |
| Very deep | >150 |

While still under the ***Soil Data Explorer*** tab, select the tab heading entitled *Suitabilities and Limitations for Use* – it's located immediately to the left of the *Soil Properties and Qualities* tab heading.

9. Determine the suitability of your soil map unit for *Dwellings with Basements*. This can be found under the *Building Site Development* tab (default settings are OK).

What is the rating? _______________

List the reason(s) for the rating _________________

10. Determine the suitability of your soil map unit for *Local Roads and Streets*. This is also found under the *Building Site Development* tab (default settings are OK).

What is the rating? _______________

List the reason(s) for the rating _________________

11. Click on the *Vegetative Productivity* tab. Determine the suitability of your soil map unit for one of the categories listed (this will vary depending on geographical location).

List the category (e.g. *Yields of Irrigated Crops*, *Range Production*, etc.)

What is the rating? _______________ (describe as needed)

12. Click on the *Waste Management* tab. Determine the suitability of your soil map unit for *Disposal of Wastewater by Irrigation* (default settings are OK).

What is the rating? _______________

List the reason(s) for the rating _________________

## GENERAL QUESTIONS

13. In your own words, give a definition of a soil map unit. A couple of sentences should be adequate to do this, but make sure your definition mentions soil series.

14. Explain why it is necessary to use soil series rather than higher levels of the classification system (i.e. order, suborder) as the basis for detailed soil mapping.

15. Based on all of the information you have found in Web Soil Survey, provide a general assessment of the selected soil map units from your AOI relative to their use and management. Describe any relevant soil or site properties that result in limitations for the variety of land uses that are assessed in Web Soil Survey.

# CHAPTER OVERVIEW

## 5: Soil Physical Properties & Soil-Water Relations

**Learning Objectives**

- Define soil texture and understand its influence on water infiltration, percolation and soil water holding capacity
- Understand the relationship between soil texture and structure
- Describe the relationships between bulk density and porosity and particle density and porosity
- Learn to calculate bulk density, particle density, and porosity of a soil sample
- Measure soil moisture to examine the influence of density and texture on water holding capacity
- Identify conditions under which soil is most susceptible to erosion by water and wind

**GOAL**: To understand soil texture and structure and their influence on soilwater relations



**Additional resources**:

- Chapter 17 (Soil Erosion and its Control) of the Brady and Weil: Elements of the Nature and Properties of Soils textbook
- Raindrop impact on a sandy surface video: https://www.youtube.com/watch?v=bmRY...nel=APSPhysics
- Wind erosion video by M&M Divide RC&D: https://www.youtube.com/watch?v=PQmon7Rj6ns (length 3:03)
- Soil data explorer available from UC Davis: https://casoilresource.lawr.ucdavis.edu/gmap/

# 5.1: Introduction- Soil Texture, Structure and Water Relations

In this lab, you will observe examples of soil textures and structures independently. Second, you will observe the effects of texture and structure on water percolation. Third, you will measure the water holding capacity of a coarse and fine textured soil. During the exercise, try to think about how the concepts you are learning can be applied to your major area of interest.

# 5.2: Bulk Density, Porosity, Particle Density of Soil

Soil is a unique three-phase system composed of solids (soil particles), liquid (water), and gases (the soil atmosphere). The characteristics and interactions among these three phases determine the soil's physical properties. Bulk density, particle density, and porosity are three soil physical properties exemplifying the relationships among the soil phases. The volume of voids in soil is related to the percentages of sand, silt and clay (soil texture) and to the arrangement of these soil particles soil structure.

The texture and structure of soil determine the size and distribution of the pores and the total porosity of the soil. This empty space in soil enables root growth, water retention, atmospheric gas exchange, and water drainage. A soil ideal for plant growth will have approximately 50% of its total volume as pore space. Sands contain less pore space than any of the other textures and clay usually has the most. The porosity of a soil can be reduced by compaction or be increased by the addition of organic matter to improve a soil's aggregation (structure).

Two factors must be known about a soil before its porosity can be calculated: bulk density and particle density (Figure 1).

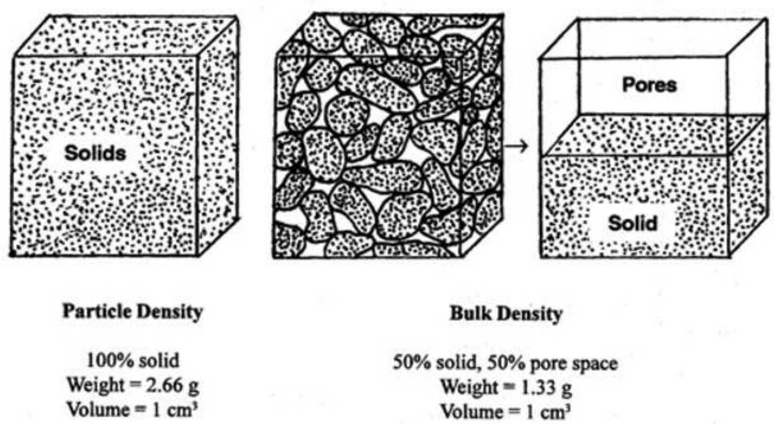



Figure 1. Illustration of the difference between bulk density and particle density by Plant and Soil Science eLibrary used with written consent.

# 5.3: Bulk Density

Bulk density is the dry mass of a soil divided by the total soil volume. The bulk density value for soil is calculated using the formula:

**Bulk Density** = mass (g) oven dry soil / total soil volume (cm$^3$)

$$D_b = \frac{ODwt}{V_t}$$

Some typical values for the bulk density of soils having different textures along with the corresponding porosity percentages are given In Table 1.

Table 1. Typical bulk density, porosity, and pore size distribution of several soils.

| | Bulk Density (g/cm³) | | Particle Density (g/cm³) | Porosity (%) | | Pore Size |
|---|---|---|---|---|---|---|
| Soil Texture | Range | Average | | Range | Average | |
| Sands & Sandy loams | 1.2 to 1.8 | 1.5 | 2.65 | 55 to 32 | 43 | Macro |
| Loams & Silt loams | 1.1 to 1.5 | 1.3 | 2.65 | 58 to 43 | 50 | Macro & Micro |
| Clay loams and Clay | 1.0 to 1.5 | 1.2 | 2.65 | 62 to 32 | 55 | Micro |

For a particular soil, the bulk density may vary due to compaction or loosening as a result of tillage operations, or other forms of soil disturbance. Variation of bulk density means the porosity will also change. Some soils (surface of forest soils, Histosols, and soils derived from volcanic ash) have very low bulk density values (often less than 1.0 gram/cm$^3$), due to high porosity.

# 5.4: Particle Density

The **particle density** of a soil = dry mass (g) of soil / volume of soil particles.

$$D_p = \frac{ODwt}{V_s}$$

Where $D_p$ is particle density; ODwt is oven-dry weight of soil; $V_s$ is volume of solids. Particle density takes into account the mass and volume occupied by the **solid particles only**. It excludes the volume occupied by air and water. Since a majority of soils is composed of particles derived from minerals containing 70% or more silica and oxygen, the particle density of most soils is approximately 2.65 g/cm$^3$ . This particle density is nearly the same as the density of quartz.

Variations in the particle density of soils are due to the presence of heavier minerals (such as iron oxides) or organic matter (which has a low density and reduces the overall particle density value). Kaolinite and illite clays have particle densities of about 2.6 g/cm$^3$ , while colloidal montmorillonite clays have particle densities of about 2.4 g/cm$^3$.

Although tillage results in a change in both bulk density and porosity, it does **not** affect particle density. The particle density remains constant because tillage and other short-term changes do not alter the total amount or the chemical composition of the soil mineral particles.

# 5.5: Porosity

Porosity (percentage of total pore space) is the volume of the soil occupied by pores.

$$\%P = \frac{V_p}{V_t} \times 100$$

Where %P is percent porosity; Vp is volume of pores; Vt is volume total (solids plus pores). The total volume of pores is usually greater in a well-structured fine-textured (clayey) soil than in a coarse-textured (sandy) soil. However, the individual pores tend to be larger in sandy soils than in clayey soils (which have many more micro pores). But why can a soil which has larger pores have less total pore space than a soil which has smaller pores?

Although a soil's total porosity is important, its **pore size distribution** is equally important. Individual pores can be categorized as macro pores and micro pores. The large (macro) pores drain quickly of excess water and allow free movement of air and water. These macro-pores promote soil aeration (free movement of gases) and enhance water infiltration, percolation and drainage. Soils containing a large proportion of macro pores are usually very sandy and tend to retain only a limited amount of water. The small (micro) pores retain much more water, and consequently drain slowly and have restricted air and water movement. Restricted soil aeration causes reduced plant growth because roots need oxygen to conduct the process of root respiration in every cell. Also, many microorganisms require oxygen - therefore, some biological and chemical reactions are inhibited by poor aeration.

**Aggregation**, or the clustering of the soil particles into aggregates, creates larger macro pores between the peds, which enhance aeration and root penetration. Within each aggregate exist smaller micro pores that function primarily to retain water. A balance between macropores and micropores is desirable for most agricultural situations to provide both adequate aeration and optimum water retention for crop growth.

*If the bulk density and the particle density of a soil are known, then the porosity can be calculated by using the following relationship:*

Since, 100 % total soil volume = % solid volume + % pore volume then, % total pore volume = 100% total soil volume - % solid volume

$$\%P = \%V_t - \%V_s$$

This last equation can be used to determine the porosity, if one recognizes the % solid volume can be obtained by dividing the bulk density by the particle density and multiplying the quantity by 100. The resulting equation becomes:

$$\%P = 100\% - \left(\frac{D_b}{D_p} \times 100\right)$$

Note, the units of bulk density and particle density must be the same for them to be able to cancel in the calculation. The term in brackets, i.e. [bulk density / particle density x 100] represents the percentage of the soil volume occupied by the soil solids. When the volume of soil solids is subtracted from 100%, the difference is the percentage of the soil volume occupied by pores, or the total porosity or total pore space.

# 5.6: Sampling

Samples for determining bulk density must be collected very carefully to ensure the sample represents the in situ condition desired and no additional compaction or loosening has occurred. One method for determining bulk density is the "core" method. A (relatively) undisturbed, cylindrical soil core (of known volume) is collected using a device like the one in Figure 2.

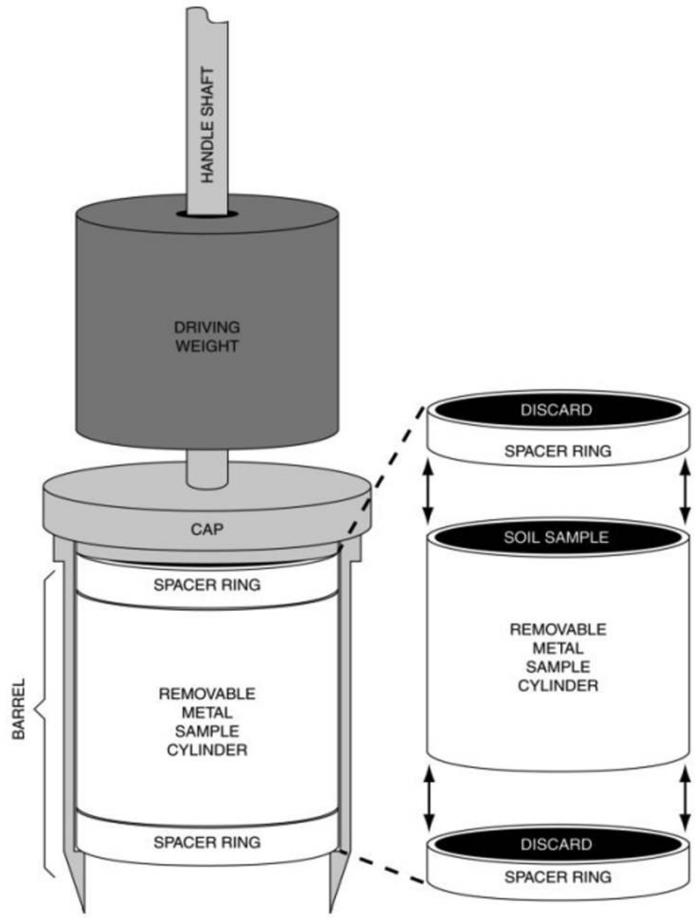



Figure 2. Uhland sampler for collecting soil samples for bulk density determinations Source: King et al. 2003.

The driving weight is raised and dropped repeatedly to drive the sampler into the soil. When the desired depth is reached, the device is removed from the soil, and the removable metal cylinder containing the soil sample is removed. With the dimensions of the cylinder and the weight of oven-dry soil inside the cylinder, we can calculate the bulk density.

Please watch the following video for proper bulk density soil sampling technique; the "core method" is what you will be using, which begins at 22:20.

Video: A video job aid on the three preferred methods for collecting bulk density samples in soils using National Cooperative Soil Survey methods and references. https://youtu.be/E7BSZrJ-TDw?t=1341

---

# 5.7: Soil-Water Relations

Soil water is of great importance because of the many biological and chemical reactions occurring due to the presence of moisture in the soil. In a completely dry soil, very few physical or chemical reactions occur. In a moist soil, many reactions occur, while in a very wet soil, a completely different set of reactions occur. Additionally, the behavior of a soil is completely altered once the moisture/saturated conditions are altered, and these dynamics are specifically dependent upon soil texture and structure.

Plants use several mechanisms to obtain water from soil. Passive absorption is the most important process and accounts for more than 90% of the water absorbed by plants. Passive absorption is the movement of water into a plant root resulting from the pulling force (suction) on soil water caused by the continuous water column moving upward through the plant as water is lost at the leaf surface by transpiration. The transpiration process is the actual cause of the water loss due to the air being much drier than the water in the plant. The more water a plant removes from a soil, the more difficult it becomes for the plant roots to continue to obtain the remaining water from the soil. The plant roots must exert a greater suction on the water in the soil pores to enable the roots to extract more water for continued crop growth.

Plants are able to use only a portion of the total water held in the soil pore space. It is convenient to think of soil water as a continuum from completely wet (saturated) to completely dry (oven dry). This continuous spectrum of soil water is conveniently separated into crop and soil response regions (Figure 3). These divisions are based mainly on the soil water potential (or suction) designated in negative kilopascals (kPa) of pressure or positive kilopascals (kPa) of suction.

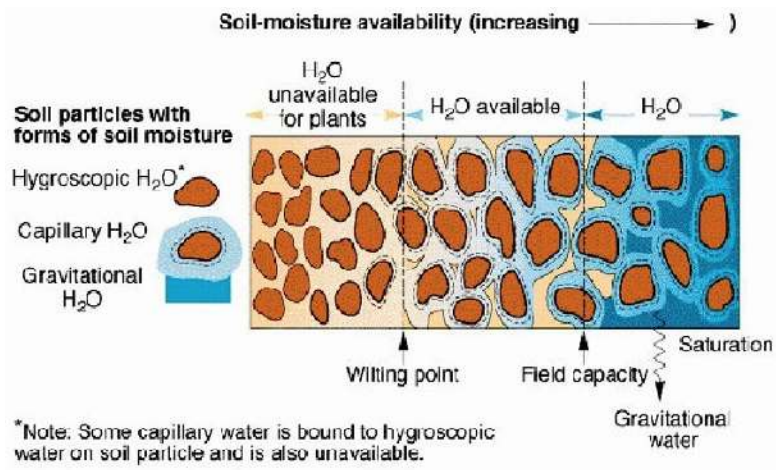



Figure 3. Detailed description of the association between crop and soil response regions and soilmoisture availability. Source: Rhoads and Yonts, 1984.

Water moves through a soil in the large pores and drains away due to the force of gravity. This water is called gravitational water. Gravitational water represents the difference in soil moisture content between the saturation condition and field capacity.

*Gravitational water* = soil moisture content at saturation - soil moisture content at field capacity.

Water held within small soil pores by adhesion and cohesion is termed **capillary water.** Only a portion of the total capillary water in the soil is available to plants. Plant available water can be obtained from the soil. **Plant available** water is the difference between the water content of a soil at field capacity and the soil water content at the permanent wilting point.

*Plant available water* = water content at field capacity - water content at permanent wilting point

**Available water-holding capacity (plant available water)** is an estimate of the water held between field capacity and permanent wilting point within the rooting zone or the top 150 cm of the soil if there is no root-limiting layer. The total water is calculated by summing the amount of water held in each horizon or portion of horizon, if the horizon extends beyond 150 cm. If a horizon or layer is unfavorable for roots, this and all horizons below should be excluded in calculating the available moisture.[1]

The relationship between available water retained per centimeter of soil and the textures is given in Table 2 below. If a soil contains many large pebbles and/or rock fragments, the volume occupied by the rock fragments must be estimated and subtracted from the total soil volume.

For example, if a silt loam A horizon is 25 cm thick and contains rock fragments which occupy 10% of its volume, the available water of the horizon would be 25 cm x 0.20 cm/cm x [(100-10)/100] = 4.50 cm of water.

To calculate the available water for a soil profile, first calculate the available water for each horizon to the nearest hundredth, sum all horizons, then round the grand total to the nearest tenth. For example, 14.92 would round to 14.9 in the low class; 15.15 would round to 15.2 in the moderate class.

Table 2. Calculation factors for water-holding capacity (Adapted from: 2018 Region VII Official Handbook)

| Available Water Calculation Factors | |
|---|---|
| **Available water (cm of water / cm of soil)** | **Texture classes** |
| 0.05 | sands, loamy sands |
| 0.15 | textures not included in the other classes |
| 0.20 | silt loam, silt, silty clay loam, peat, muck, mucky peat |
| **The available water classes are:** | |
| Very low. Up to and including 7.5 cm of water | |
| Low. Greater than 7.5 cm of water but less than or equal to 15.0 cm of water | |
| Moderate. Greater than 15 cm of water but less than or equal to 22.5 cm of water | |
| High. Greater than 22.5 cm of water | |

For most field crops, the **permanent wilting point** is equal to -1500 kPa of water potential or 1500 kPa of water suction. When a soil is air dry, the water present is held at water potentials ranging from -3000 to –10,000 kPa. The water in air dry soil is in equilibrium with the soil pore atmosphere which has about 98% relative humidity. The Hygroscopic Coefficient is the condition when the last micro pore is drained of water and only films of water exist surrounding the soil particles. Soil dried at 105°C to a constant weight is considered oven dry. The oven dry weight of soil is used as the reference weight to quantify the amount of water in mineral soils for all moisture conditions. **Hygroscopic water** is the water held between the Hygroscopic Coefficient and Oven dry.

*Hygroscopic water content* = Water held below the Hygroscopic Coefficient - Oven dry mass

[1] For available water calculations, the properties of the lowest horizon designated for description can be assumed to extend to 150 cm, if the presence of a restrictive layer is not evident. If a restrictive layer is present between the lowest described horizon and the 150 cm depth, the depth to the restrictive layer should be considered for available water estimations. Materials not suited for plant root growth include: (i) horizons with coarse sand textures and some unfilled voids located directly underneath a horizon of finer-textured soil materials (i.e., textures of very fine sand, loamy very fine sand or finer), (ii) bedrock, (iii) fragipans, (iv) densic materials, (v), horizons cemented across 90% or more of the soil profile, and (vi) SiC, C, or SC textures that are very firm or firmer and have structureless grade and massive shape of structure.

# SECTION OVERVIEW

## 5.8: Soil Erosion

Worldwide there are approximately five billion hectares of degraded land, which is approximately 43% of the Earth's land surface. Of those five billion hectares, the most common cause of degraded land (two billion hectares) is soil degradation due to erosion, compaction, surface crusting, acidification, or salt accumulation. Most of that degradation (85%) comes from water and wind erosion, however, other human activities such as overgrazing, industrial activities, unsustainable agricultural activities, overexploitation, and vegetation removal cause many negative side effects on the land ultimately causing degradation of the soil (Figure 4).

| Type | Causes (not one to one along row) | Degradation process | Impact on soil processes |
|---|---|---|---|
| Physical | Deforestation | Breakdown of soil structure, aggregation and porosity | Reduction in infiltration capacity<br>Changes in soil water-retention characteristics |
| | Biomass burning | Crusting and surface sealing | Increase in runoff rate and amount |
| | Tillage up and down slope, excessive animal, human, and machine traffic, overgrazing | Compaction of surface and subsoil, reduction in proportion and strength/stability of aggregates | Accelerated erosion by water and wind<br>Increase in bulk density leading to reduction in porosity<br>Water logging and anaerobiosis |
| Chemical | Irrigation with poor quality water, inadequate drainage | Salinization, alkalinization | Accumulation of base-forming cations |
| | Little to no use of fertilizers | Nutrient depletion | Decreased levels of macronutrients on exchange sites, soil organic matter, and in soil solution |
| | Excess use of fertilizers | Acidification, eutrophication | Leaching and runoff of nutrients to water sources |
| | Application of industrial, urban wastes | Toxification, contamination with heavy metals, pollution | Excessive build up of some elements (e.g., Al, Mn, Fe) and heavy metals (e.g., lead and mercury); increase in soilborne pathogens |
| Biological | Removal of or burning residues | Depletion of soil organic carbon | Reduction in N mineralization, soil aggregation, and related properties |
| | Little or no use of organic inputs | Decline in diversity and abundance of soil biota | Shift in species composition and diversity of favorable soil organisms |
| | Monoculture, excessive tillage | Loss of soil structure | Reduction in porosity and infiltration, reduction in activity of soil biota |

Figure 4. The negative side-effects (physical, chemical, and biological) caused by various human impacts that degrade soil. Source: Palm et al., 2007.

**Soil erosion includes two separate processes** – soil erosion by water, and by wind.

*Water erosion*… begins with detachment as rain drops bombard soil aggregates, separating some of them from the aggregate. These stand-alone soil particles are much smaller and are more easily transported. The transported particles are eventually deposited in a low-lying area, completing the three-part process of detachment-transport-deposition (Figure 5). Transport can happen due to splashes from the raindrop, or from running water carrying sediment downhill.

Water erosion is initiated by sheet erosion where splashed soil is moved uniformly, but some columns of soil that were protected by pebbles may remain. When the water gathers into small channels due to irregularities in the landscape, those channels incise into the soil surface forming a rill. Rills can be smoothed by tillage equipment. If enough water gathers, a gully can form, which is essentially a large rill that is so deep that it cannot be smoothed by tillage equipment. Interrill erosion is sheet erosion that occurs between rills. The majority of soil erosion is due to sheet and rill erosion.

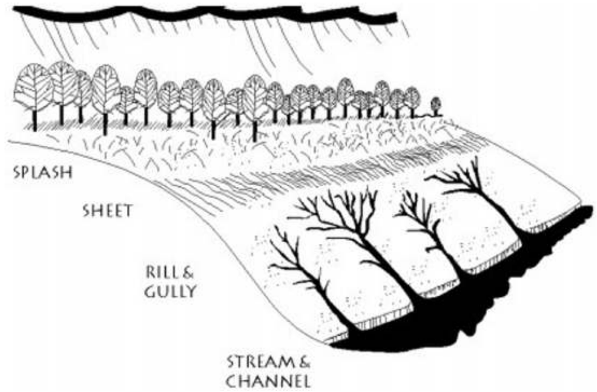


Figure 5. The effects of water erosion across the soil-landscape. Source: trival.co

*Wind erosion*… is greatest in arid and semiarid regions, such as Wyoming, though it can occur to some extent in humid regions. Similar to water erosion, wind erosion involves three processes – detachment, transportation, and deposition (Figure 6). Detachment occurs as heavy winds push and bounce heavy particles along the surface. As this happens, silt and clay particles can be broken away from aggregates and can become airborne and transported for great distances. The sediment is transported by three methods – saltation, soil creep, and suspension.

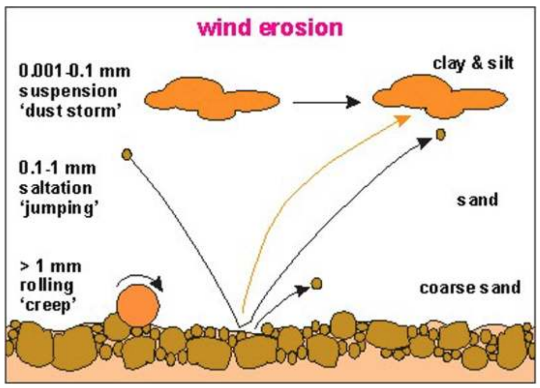


Figure 6. The effects of wind-erosion on soil. Source SeaFriends.

*Read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

---

# 5.9: Activity 1 - Bulk Density and Porosity of Soil Cores

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

*Step 1*: Three soil cores are displayed in metal cylinders. The volume of the cylinders and the mass of dry soil in each core are given. Using these data, determine the bulk density of each soil sample. Assume the particle density of the soil in all cores is 2.65 $g/cm^3$. Calculate the % porosity for each sample. Record the data and include the soil texture and soil condition (disturbed, compacted, or undisturbed) of each soil sample. Core volume $V = \pi r^2 h$.

| Core | Description of soil texture and structural condition | Mass dry soil (g) | Bulk Density ($g/cm^3$) | Porosite (%) |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| Core volume ($cm^3$) | | | | |

*Step 2*: Now that you have practiced calculating bulk density and porosity, you will do the same calculations for your prepared soil samples collected in the first week of lab.

Show your detailed Bulk density and porosity calculations:

Bulk Density = ___________ $g/cm^3$

Porosity = ___________ %

*Bulk Density Questions*

1. Explain how the addition of organic matter to these soils would affect their bulk density.
2. Which of these soils will usually have the higher bulk density, the sandy soil or clayey soil? Why?
3. How does your bulk density value from your ring sample compare with those given in Table 1?
4. Calculate the bulk density of a soil with a porosity of ___30%___ by using the porosity formula and assuming the particle density of this soil is 2.65 $g/cm^3$.

# 5.10: Activity 2 - Soil Moisture

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

1. A soil has ____15%___ water (on mass basis) when saturated, ___8%____ water at field capacity, ___5%___ water at the permanent wilting point, and ___2%____ water at the air dry condition. The soil weighed ___1.75_____ grams per cubic cm when oven dry.
   - The percentage of water available to plants at field capacity = _____________
2. A moist sample of soil weighs 121.9 grams and contains 21.9 % moisture.
   - The oven dry mass of this soil = ______________

# 5.11: Activity 3 - Soil Water Movement

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

At your lab bench you will have 3 different soil texture classes (soils A, B, C) arranged in a funnel that has been prepared with a filter at the bottom. You will add a designated amount of water (50 mL) to each of the soil samples and record the time it takes before you see water move through the other end. After 2 minutes has passed you will also measure the amount of water that flowed through the soil into the catchment beaker. Record all observations below and answer the following questions:

| | | |
|---|---|---|
| SOIL A → | Time = | Volume water that flowed through = |
| SOIL B → | Time = | Volume water that flowed through = |
| SOIL C → | Time = | Volume water that flowed through = |

1. Out of the following textures below, please indicate which was SOIL A, B, or C.
    - Sand =
    - Silty Clay Loam =
    - Clay =
2. Which texture class did the water move through the fastest? The slowest?
3. Why do you think this occurred?
4. What is a practical application of this method? (Aka why would you want to know this specific information about the soil?)

# 5.12: Activity 4 - Infiltration Estimates and Available Water Calculations

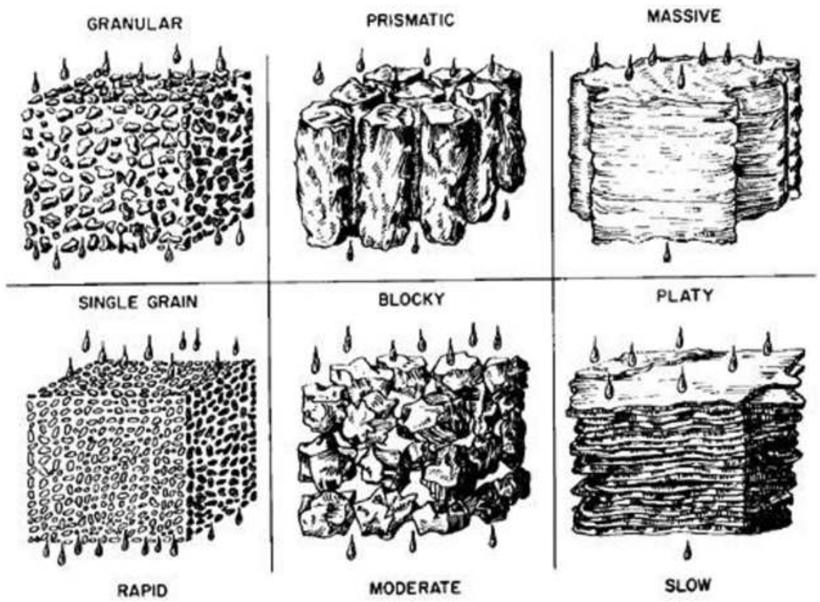
Name: ______________________________

Section: _____________________________

Student ID#:__________________________

For this activity you will estimate and calculate the available water holding capacity of a soil using properties of structure and texture.

*Step 1*: Observe the range soil profile set out by your instructor. Determine the structure of each soil horizon using your red field guidebooks. Using the figure below, correlate the structure determined for each horizon to the rate of infiltration. Select the dominant rate of infiltration as your final estimate.




| Horizon | Structure |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |

## Infiltration estimate

*Step 2*: Determine the texture for each soil horizon within the range soil profile. Based on your results and the relationship of texture and infiltration (which you just learned in Activity 3), what do you estimate the available-water holding capacity will be, (circle one of the following options on the following page):

| Horizon | Texture |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |

The available water classes are:

- **Very low**. Up to and including 7.5 cm of water
- **Low**. Greater than 7.5 cm but less than or equal to 15.0 cm of water
- **Moderate**. Greater than 15.0 cm but less than or equal to 22.5 cm of water
- **High**. Greater than 22.5 cm of water

*Step 3*: You will now calculate the available water holding capacity of your soil using your predetermined textures, the depths of each horizon, and the following information on coarse fragments provided below. Use Table 2 provided in the soil-water relations section to determine the calculation factors for each soil texture. Calculate the water holding capacity according to instructions provided in the text above, and assume that the depth boundary of the last horizon is 150 cm.

| Horizon | Depth | Texture | Available water calculation factor | % Coarse fragment in horizon |
|---|---|---|---|---|
| 1 | | | | 0 |
| 2 | | | | 5 |
| 3 | | | | 15 |
| 4 | | | | 20 |

Using the information in the table above, calculate your available-water to a depth of 150 cm for this range soil and using your final answer determine the final available-water class of this same soil:

Available-water calculated for soil profile = ________________________

Available-water class = ________________________

*Follow-up questions:*

1. Do your estimated infiltration rates and calculated available-water holding capacity make sense together? Please explain the relationship between the two, and **why or why not** they make sense together.
2. Did your estimated available-water holding capacity match your calculated available-water holding capacity? If not, where could you have assumed or calculated incorrectly?
3. Based on your final calculation would plants grow well in this soil? Why or why not?

# 5.13: Activity 5 - Effects of Soil Erosion

Name: ______________________________

Section: ____________________________

Student ID#:__________________________

To better interpret that understandings of soil erosion, you will draw a BEFORE and AFTER erosion picture of an ecosystem of your choosing. Use elements and concepts outlined in Figure 4 to detail and label your drawings and incorporate AT LEAST 3 elements of erosion into your drawing. One of these elements must focus on water-erosion and one element on wind-erosion, the rest are up for you to decide!

The BEFORE picture will be used as a "control" system showing a pristine system, and your "AFTER" will detail the effects of soil erosion. Your pictures should detail both above ground and below ground (soil) effects of erosion.

Accompanying your BEFORE and AFTER drawings, please tell us a brief story **(3-5 sentences)** on how your soil degraded over time and how that impacted soil processes and ecosystem function.

*BEFORE*:

*AFTER*:

*What happened to this system and its soil?* (Describe below)

## REMINDERS/Assignments for next week's lab:

a. Study for pre-lab Quiz on material from Lab #6: Science Communication
b. Choose one of the resources to read to prepare for lab
c. Prepare 4-5 facts on a chosen soil science topic that interests you. This could relate to something we have learned in lab or lecture, another course, work outside the university or a soil science-related cause you care deeply about. These facts will be the skeleton for next week's assignment.

# CHAPTER OVERVIEW

## 6: Science Communication

**Learning Objectives**

- To understand what it means to “effectively communicate” scientific ideas and information
- To use multiple methods of communication to translate scientific concepts to different audiences
- To create your own infographic pertaining to a topic/facet of soil science

**GOAL**: To learn how to effectively communicate scientific ideas and understandings to a variety of audiences – with a focus on soil science!



**Additional resources:**

- International year of the soils infographics - http://www.fao.org/soils2015/resourc...fographics/en/
- Nature blog on the power of infographics to communicate science – http://blogs.nature.com/ofschemesand...nicate-science
- Mind the graph blog post series on how to create infographics - https://blog.mindthegraph.com/how-to.../#.XETtrehKg2w

We will use canva.com in order to create quick and specially designed infographics, please sign up and familiarize yourself with this FREE program before class!

## 6.1: Introduction

### INTRODUCTION

Science communication is a growing area of practice and research and withholds particular value for natural sciences. Science communication is recognized as the public communication of science-related topics. The act of communicating science is carried out in many ways, encompassing science journalism, blogging, social media, videos, art, academic publishing, and any other activity that aims to help people understand anything related to research findings or the scientific process. Science communication is primarily broken down into two facets: 1) The science of science communication; and 2) The practice of science communication. The science of science communication breaks down what works effectively for communicating science, how it works, and why it works. While the practice of science communication is the actual implementation of communicating scientific ideas to a variety of audiences – and often multiple audiences!

### WHY Communicate Science?

"When scientists are able to communicate effectively beyond their peers to broader, non-scientist audiences, it **builds support for science**, **promotes understanding** of its wider relevance to society, and encourages more **informed decision-making** at all levels, from government to communities to individuals. It can also **make science accessible** to audiences that traditionally have been excluded from the process of science. It can help **make science more diverse and inclusive**."

(*Feliú-Mójer, 2015, Scientific American)*

### PROS and CONS of Science Communication

Science communication can be perceived in many ways, which is both the benefit and drawback of this field. However, if approached in the correct manner, effective science communication ultimately proves to be more of a positive tool than a negative practice.

*Pros/benefits:*

- Increased public *science education*
- Potential to effect *societal change*
- Helps scientists improve their *grasp of their own field* through the development of communication materials at multiple levels
- *Inspires* future young scientists to pursue careers in science
- Develops scientists' *toolkits* by learning skills including leadership, organization, and creativity
- *Expands* science networks through interaction with more scientists who share similar or adjacent research interests

Cons/drawbacks:

- Fear of not being viewed as *professional*
- Being taken out of context
- Someone taking your ideas
- Taking valuable time needed for doing research

## 6.2: Activity

For the remainder of the lab period we will work on creating your own infographic focused on a specific subject or facet of soil science. In this exercise you will start by taking your 4-5 prepared facts and organizing them into an aesthetically pleasing and informative infographic created specifically for a target audience (identified before creating your infographic). 4-5 facts is just your base, and students are welcome to use up to 10 facts. We highly encourage students to incorporate graphs, brief statistics, figures, and images within the infographic. The overall goal of this exercise is to practice translating your knowledge of soil science into a brief, impactful, and accurate deliverable used to communicate your science!

*Instructions for creating your infographic in-class:*

a. To begin, go to canva.com

b. Students can sign up for this FREE graphic design site

c. After you are signed up type "infographic" into the search bar to bring up the infographic template

d. Once you have brought up the editable template, follow the basic steps of the program and explore what the different tools available can do.

e. It is time to create!

f. Note: not all graphics are free to use, and you won't be able to download your infographic without paying. To avoid this, find graphics that are open source.

***OUTCOMES**:* At the end of the lab period you are required to submit a PDF of your infographic to your laboratory instructor. The TOP 3 infographics from each lab section will move on to a class-wide competition for TOP INFOGRAPHIC selected by your professor. Top infographics will be rewarded for their work!

*A few tips on infographics before we get to creating:* *(adapted from: nielpatel.com)*

a. **Create your infographic for your target audience**

b. **Keep it simple**- you only have so much space

c. **Keep it focused**- you don't need to say all the things!

d. **Show things visually**

e. **Make it easy to view** – picture quality/clarity, font size, font type, color combinations

f. **Make it a manageable length and size** – Bigger isn't always better, and vice versa.

g. **Add white space** – people's eyes need a break too.

h. **Create a killer headline** – catchy, witty, short, and to the point… and accurate!

i. **Focus on the flow** – transition smoothly between facts and images to create a story

j. **Check your facts and figures**- you only have so many, so you want to make sure they are right, otherwise there will be blaring errors and that's what will catch folks' eyes.

k. **Cite your sources**

*Please read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

1. *Describe in your own words what science communication is and how it can enhance scientific research efforts*
2. *How have you ever implemented the practice of science communication into any of your previous work or studies?*
3. *How did you find this exercise useful for communicating science?*
4. *Who is your target audience for this infographic?*
5. *What did you like about this exercise?*
6. *What didn't you like about this exercise?*
7. *If any, what other skills or outcomes would you have preferred to develop regarding the practice of science communication*

# CHAPTER OVERVIEW

## 7: Soil Chemistry

**Learning Objectives**

- To learn about the variety of soil colloids that exist
- To understand the fundamentals of soil charge, including isomorphic substitution and cation exchange capacity
- To become familiar with how pH and electrical conductivity affect soil functions and processes and how to measure these parameters
- To better understand the concepts and processes behind soil redox reactions

**GOAL**: To understand key aspects of chemical nature, properties, and reactions in the soil-environment.



**Additional resources**:

- Video link: Soils Sustains Life: https://youtu.be/vDL6F6GkAzI (length 2:54)
- Video link: The Science of Soil: Why Study Soil? https://youtu.be/og3TUc9xQaE (length 4:19)

# 7.1: Introduction

Soil Chemistry is the branch of soil science that deals with the chemical composition, chemical properties, and chemical reactions in soil. The soil environment is dynamic and comprised of a heterogeneous mixture of air, water, and inorganic and organic solids. Soil chemistry is primarily concerned with the chemical reactions associated with the many phases incorporated within the soil mixture. Soil chemistry is an ever-expanding field that traditionally focused on chemical reactions that affected plant growth and nutrition, and has since expanded to include water and soil contaminants and their effects on plants, animals, and humans.

Soil is made up of inorganic and organic assemblages, in the form of solids, liquids, and gases. Elemental content varies among soil types, however, the elements found in the highest quantities are typically O, Si, Al, Fe, C, Ca, K, Na, and Mg (in order of highest to lowest natural abundance). Inorganic components of soil makeup approximately 90% of all solid components, however, soil organic matter (SOM) still plays a critical role in chemical reactions within the soil. In addition, properties such as size, surface area, and charge behavior affect the majority of the essential equilibrium and kinetic reactions and processes which occur in soils (Figure 1).

In this lab we will cover important chemical reactions in soil, the properties that affect chemical reactions in the soil, and how to measure specific chemical properties in soils.

## SOIL COLLOIDS

The extremely small, colloidal particles (smaller than 0.002 mm) of clay and humus control many important chemical and physical properties of the soil. This portion of the soil is often called the "active fraction", comprised of highly reactive materials with electrically charged surfaces. The small size of colloids results in a large surface area per unit weight, and their ionic structure results in a net electrical charge.

The type, amount, and mineralogy of colloids will strongly influence most land management decisions. For example a soil that is 40% of clay that primarily consists of smectite (a 2:1 shrink-swell clay) could have limitations for constructing roads, or building foundations due to the shifting of the soil as the soil wets and dries. Such a soil could be highly productive for row crop agriculture though, due to the high amount of charge that facilitates the retention of nutrients like $Ca^{2+}$, $K^{+}$, $Mg^{2+}$, etc. On the contrary, a soil such as an Oxisol that has 80% clay has colloids that are primarily aluminum and iron oxides, which do not shrink or swell, and have a low amount of charge. Thus, the soil would be well suited for building foundations.

### General properties of soil colloids

*Size:* smaller than what can be seen with a normal light microscope

*Surface area:* The smaller the size of the soil particles the greater the surface area. Higher surface area increases the availability of reaction sites for processes such as adsorption, catalysis, precipitation, microbial colonization, etc. Some colloids may also possess extensive internal surfaces, depending on crystalline units present.

*Surface charge:* colloids carry positive and/or negative electrostatic charges, whereby negative charges typically outweigh positive charges. Charge is sometimes pH dependent. Colloid charge helps to attract or repulse various substances in the soil solution or environment.

### Types of soil colloids

*Crystalline silicate clays:* Clay types vary based on the number and combinations of structural units. The structural units are characterized by either tetrahedral units ($Si^{4+}$) or octahedral units ($Al^{3+}$, $Mg^{2+}$, and $Fe^{2+}/Fe^{3+}$) (Figure 2). Individual units link together to form “sheets” of tightly bound and tightly packed 0-Si-Al atoms, which combine to form the layers which give the clay its characteristic crystalline structure. The size and location of layer charge varies due to the process of isomorphic substitution, which occurs in the layered sheets (Figure 2). Crystalline silicate Clays are typically categorized into two categories: 1) 1:1 clays; and, 2) 2:1 clays.

*1:1 Clays*- (i.e. Kaolinite)

- One tetrahedron and one octahedron sheet
- Non-expanding, no shrink-swell action

- Little isomorphic substitution
- Found in highly weathered soils

*2:1 Clays*- (i.e. smectite, vermiculite, and mica)

- One octahedral sheet between two tetrahedral sheets
- Have a variety of shrink-swell potentials, favoring increased shrink-swell action
- Charge dominated by isomorphic substitution
- Isomorphic substitution occurs in the… octahedral (smectite), tetrahedral (mica), and tetrahedral (vermiculite)

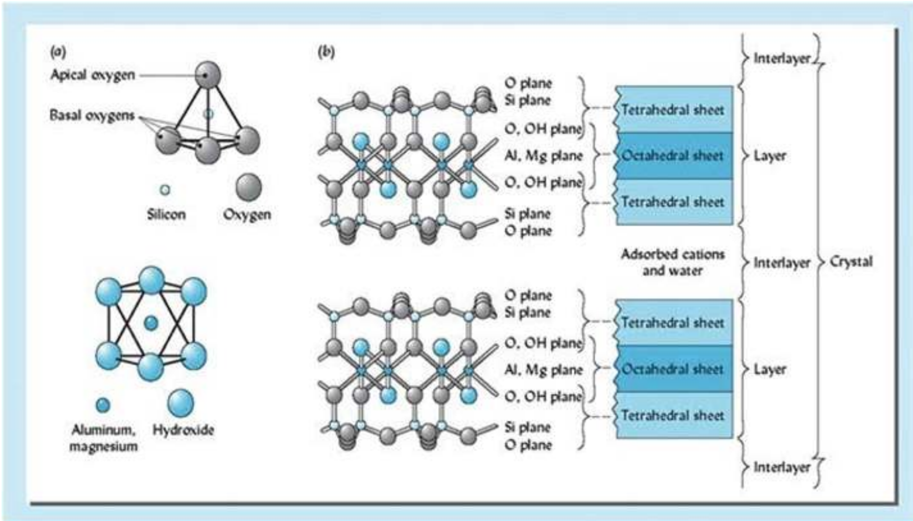



Figure 1. "The basic molecular and structural components of silicate clays" (a) (top) Si tetrahedral structure versus, (bottom) Al, Mn octahedral structure, and b) orientation of tetrahedral and octahedral sheets forming layered crystalline structure. Adapted from "The Nature and Properties of Soils" Brady and Weil, 2008.

*Noncrystalline silicate clays:* These clays also consist of tightly bonded Si-Al-O atoms, oriented into unordered, noncrystalline sheets. They are characterized by high water holding capacity and extremely high capacities to strongly absorb phosphate and other anions, particularly under acid conditions. Examples of noncrystalline silicate clays include, allophane and imogolite, typically found in Andisols, or soils derived from volcanic ash.

*Iron and aluminum oxides:* these properties are present in many soils but are highly expressed in highly weathered soils of warm, humid regions. They consist of either Fe or Al atoms combined with O atoms, with a net charge that ranges from slightly negative to moderately positive. Examples of iron oxides include crystalline goethite and soil coatings. Examples of aluminum oxides include crystalline gibbsite and soil coatings.

*Organic material/humus:* Organic colloids or humus, are especially important in the upper portions of a soil profile. Because these colloids are not mineral material, alternatively, they consist of complex chains and rings of carbon atoms bonded to H, O, and N. These colloids are often the smallest in size, have a net negative charge that varies with soil pH, and have a high capacity to absorb water.

## SOIL CHARGE

Now that we have prefaced the basics of soil colloids, it is important to highlight some of the important processes which contribute to the potential charge of a soil. To begin, there are two kinds of charge within a soil: 1) Permanent charge and 2) Variable charge.

1. *Permanent charge:* this charge is determined from isomorphic substitution which takes place in the clay fraction of the soil between phyllosilicate layers of crystalline silicate clays.
2. *Variable charge:* this charge is predominantly pH dependent and results from reaction of $OH^-$ associated with the following
    - Edges of clay minerals
    - Organic material
    - Aluminum and iron oxides

## Isomorphic substitution

Is the process by which one element fills a position originally filled by another element of similar size (ionic radii). This process typically occurs between Si, Al, and Mg ions held within octahedral and tetrahedral structures, whereby they are replaced by a cation of similar size (Figure 3). This replacement alters the overall charge and nature of silicate clays. For example, if $Mg^{2+}$ substitutes $Al^{3+}$, overall charge balances in favor of a negative charge from the presence of O, and the resulting sheet is left with a net negative charge (Figure 4).

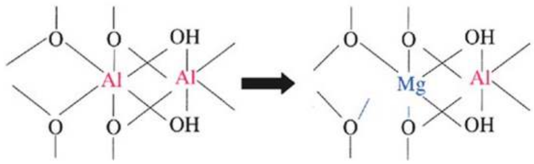



Figure 2. "Permanent charge due to isomorphic substitution" Example of isomorphic substitution whereby Mg replaces the position of Al, still maintaining crystalline structure.

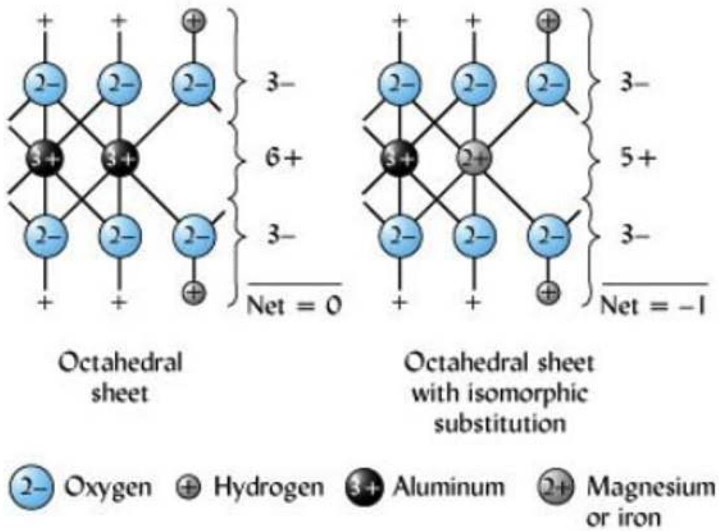



Figure 3. Charge calculations determined for the substitution of one Mg in place of an Al ion. Adapted from "The Nature and Properties of Soils" Brady and Weil, 2008.

## Cation Exchange Capacity

Ion exchange is one of the most significant features of the clay and humus fractions. The capacity of the particles to attract or adsorb cations is called the cation exchange capacity (CEC). This soil property is very important for plant uptake of nutrients and buffering against soil acidification. Clay minerals and organic components of the soil have negatively charged sites which can absorb positively charged cations and hold those cations on their surfaces by electrostatic force. This ability allows the soil to serve as a storehouse of plant nutrients like potassium ($K^+$), calcium ($Ca^{2+}$), and magnesium ($Mg^{2+}$), also referred to as *base cations*. Measuring base cations in a soil will give a good idea of that soil's CEC.

Because many plant nutrients exist as cations, CEC is critical for plant growth. A soil with high clay and organic matter will have more negatively charged sites for cations and therefore have a greater CEC and are more fertile for plants. However, in an agricultural setting, crops can be grown on soils with low CEC and still be productive with amendments. The reactive exchange capacity of the soil also permits it to serve as a filter or treatment medium for land application of waste materials.

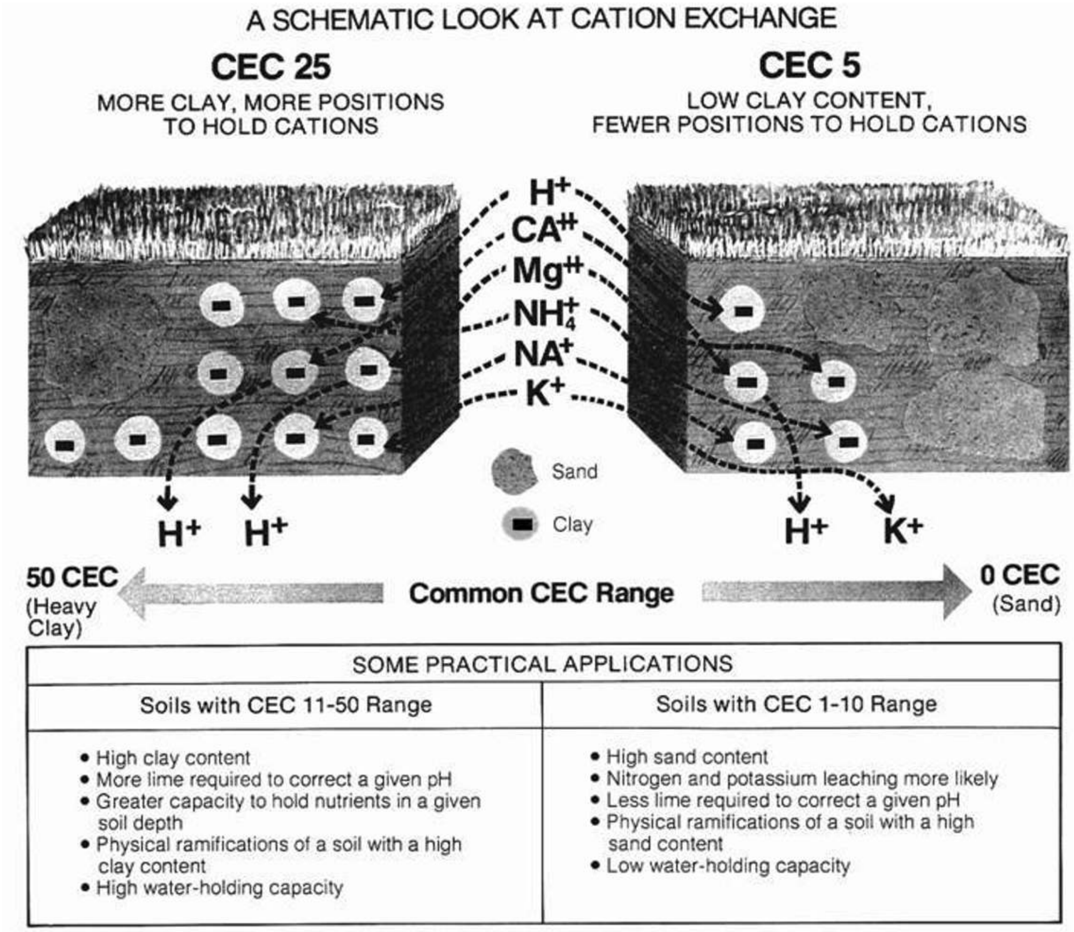



Figure 4. "A schematic look at cation exchange" by Spectrum Analytic Inc.

### Determining Cation Exchange Capacity

The cation exchange capacity (quantity of cations a soil can adsorb per unit weight, CEC) can be determined using a simple displacement process (Figure 5).

1. Soil sample is first saturated with a simple cation like $NH_4{}^+$ so all the negative charge sites are occupied by $NH_4{}^+$.
2. Excess $NH_4{}^+$ (i.e., not on exchange sites) is removed by leaching with ethyl alcohol.
3. Another cation such as $Ba^{2+}$ is used to displace all the $NH_4{}^+$. The $NH_4{}^+$ is collected in the filtrate and measured. The quantity of $NH_4{}^+$ collected from the sample is the quantity of cations that the soil can hold, i.e. CEC.

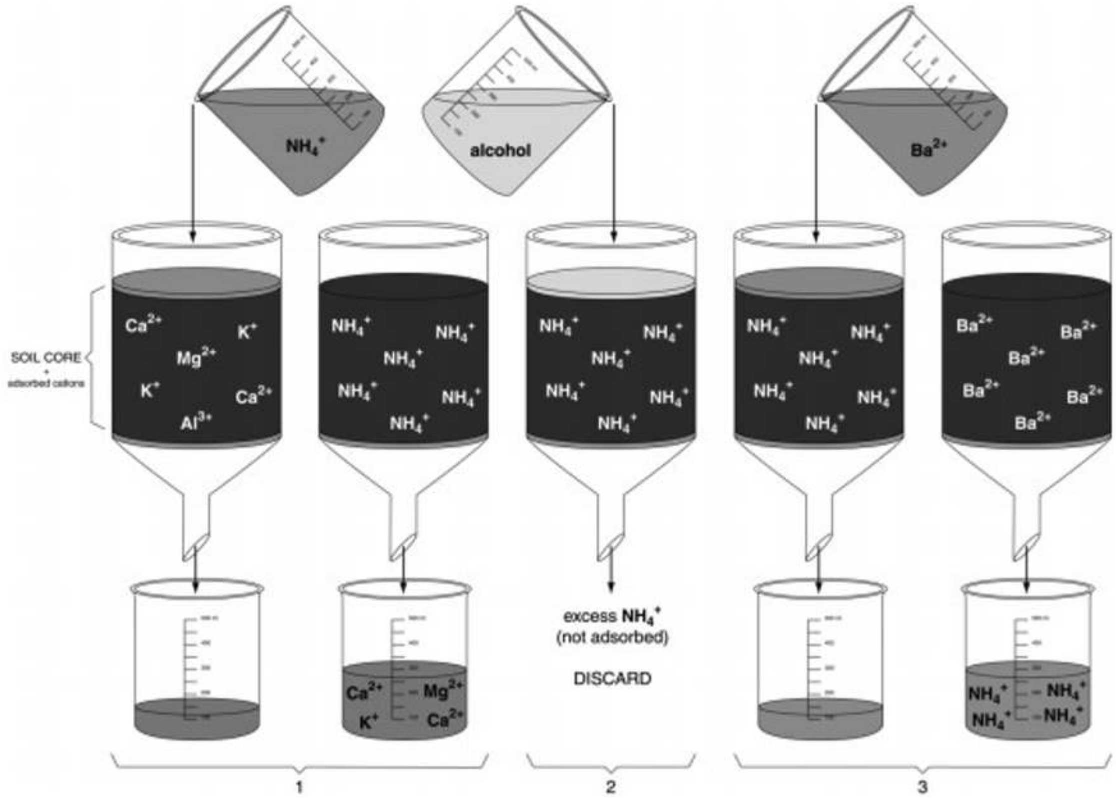



Figure 5. "Schematic of process for determining cation exchange capacity" by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

## Calculating CEC

*The Sum-of-Cations Method:* If you have a soil analysis where the quantities of all cations in the soil are listed, simply summing all those exchangeable quantities will yield the CEC you found in the preceding problems.

*The "Mineralogy" Method*: As you know from your reading and class discussion, clay minerals have a range of values for CEC. If the mineralogy of the clay fraction is known (that is, the type and amounts of each clay mineral), then the CEC can be approximated.

To make these calculations easier, Table 1 contains representative values for CEC to use in all calculations for this class unless otherwise noted. In nature, however, these soil colloids will have a range of values.

Table 1. “"Typical CEC of various soil colloids"” by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

| Mineral or colloid type | CEC of pure colloid ($cmol_c$/kg) |
|---|---|
| kaolinite | 10 |
| illite | 30 |
| montmorillonite/smectite | 100 |
| vermiculite | 150 |
| humus | 200 |

*Example:* Using the mineralogy approach to CEC calculations, consider a soil having 100% clay where the clay is 100% kaolinite. The CEC would then be 10 $cmol_c$/kg. If a soil contains only 10% kaolinite (or 10 kg clay in 100 kg soil), however, this clay would contribute:

$$\text{Total CEC of the soil} = \frac{10\ \text{cmol}_c}{\text{kg clay}} \times \frac{10\ \text{kg clay}}{100\ \text{kg soil}} = \frac{1.0\ \text{cmol}_c}{\text{kg soil}}$$

## Soil pH

By definition, pH = -log [$H^+$]. The pH of soil is a critical factor for the fate of many chemical processes and the variable charge of soil. Soil pH is also incredibly important for plant growth: certain plant essential nutrients are only available within certain pH ranges. Plant optimal pH ranges vary greatly. Some plants excel in low pHs (e.g. blueberries) while others are adapted to high pHs (e.g. asparagus) (Figure 7). For agriculture, if the soil pH is not desirable for the given crop, it can be adjusted. The addition of lime can raise the pH while adding organic matter or ammonium fertilizer can lower the pH.

## Soil Electrical Conductivity

Electrical Conductivity (EC) is the measure of the amount of salts in soil, or salinity. EC varies by soil type, texture, and location (Figure 8). EC is very relevant in the Western U.S. as well as in tidal zones in coastal areas. EC affects multiple facets of soil health including soil-water balance and soil microbe activity. The negative effects on the soil-water balance can be devastating to plants: saline soils have a lower water potential than what is within plants, causing water to move from the plants to the soil. This loss of water causes drought stress to the plants. High levels of salinity are common in the West because of the drier climate. With lack of water movement through the soil profile the salts are not flushed out of the soil and accumulate near the surface. There are many ways to properly manage a soil that has an EC higher than desired, including limiting nitrogen fertilizer (which can increase salinity) as well as practicing no-till agriculture to retain soil moisture.

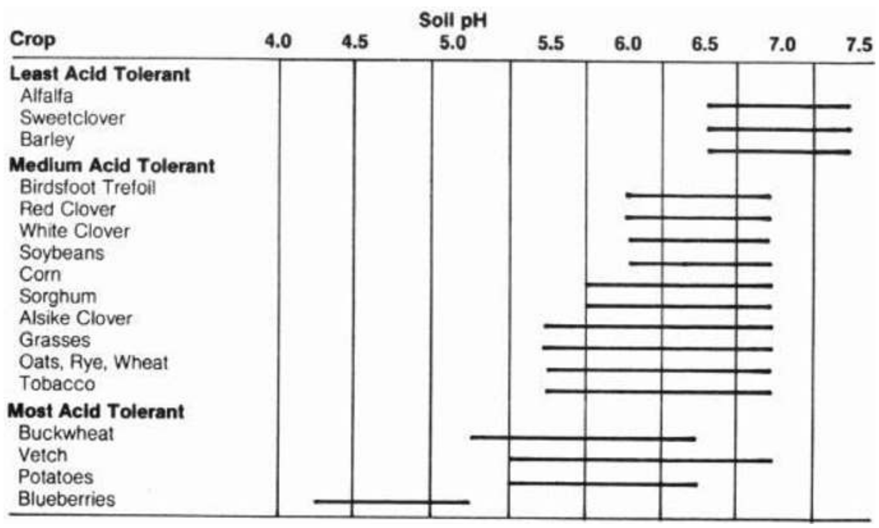



Figure 6. Mineral soil pH ranges for crops by Keith Johnson, used with written consent.

**Table 2. Salinity classes and relationship between $EC_{1:1}$ to ECe values (Smith and Doran, 1996 adapted from Dahnke & Whitney, 1988).**

| Texture | Degree of Salinity (Salinity Classes) | | | | | |
|---|---|---|---|---|---|---|
| | Non-Saline | Slightly Saline | Moderately Saline | Strongly Saline | Very Saline | Ratio of $EC_{1:1}$ to ECe |
| $EC_{1:1}$ Method (dS/m) | | | | | | |
| Coarse to loamy sand | 0-1.1 | 1.2-2.4 | 2.5-4.4 | 4.5-8.9 | 9.0+ | 0.56 |
| Loamy fine sand to loam | 0-1.2 | 1.3-2.4 | 2.5-4.7 | 4.8-9.4 | 9.5+ | 0.59 |
| Silt loam to clay loam | 0-1.3 | 1.4-2.5 | 2.6-5.0 | 5.1-10.0 | 10.1+ | 0.63 |
| Silty clay loam to clay | 0-1.4 | 1.5-2.8 | 2.9-5.7 | 5.8-11.4 | 11.5+ | 0.71 |
| ECe Method (dS/m) | | | | | | |
| All textures | 0-2.0 | 2.1-4.0 | 4.1-8.0 | 8.1-16.0 | 16.1+ | NA |

Figure 7. "EC ranges for a variety of soil textures" by USDA NRCS

## REDUCTION-OXIDATION (redox) REACTIONS IN SOIL

Alternating oxidizing and reducing conditions in soils influence a number of critical chemical reactions, the potential for plant growth, soil organic matter dynamics, and the survival of organisms. The quantification of reducing soil conditions is driven by saturated soil conditions and is particularly important in the assessment of wetland function and identification of hydric soils.

The redox ladder (figure 8) serves as a useful guide indicating the hierarchy of chemical compounds used as terminal electron acceptors (TEA) during microbially mediated reduction reactions (Figure 9). The various compounds are utilized as TEAs at specific redox potential (Eh) ranges and are impacted by pH as well.

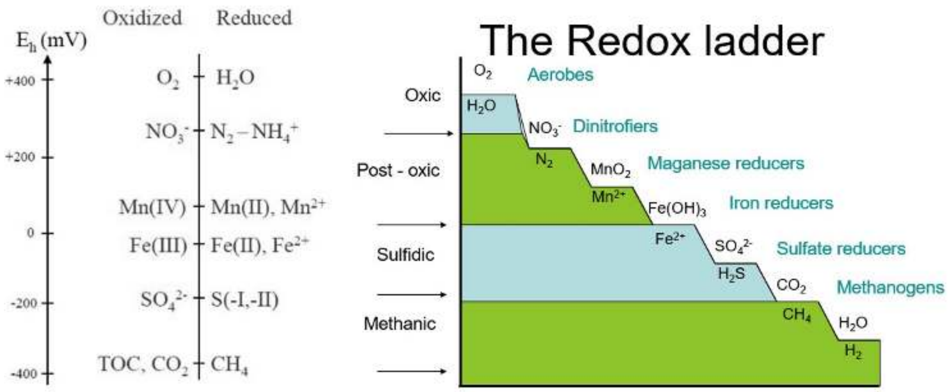



Figure 8. The redox ladder and associated redox potential (Eh) thresholds by Vaughan & Duball, 2019.

## Redox Diagrams

Redox conditions in soil are represented on a Redox diagram, which displays Eh versus pH (Figure 10). By determining the pH and the Eh and finding the point of intersection on the Redox diagram one can obtain a fairly good idea about the general nature of the soil system.

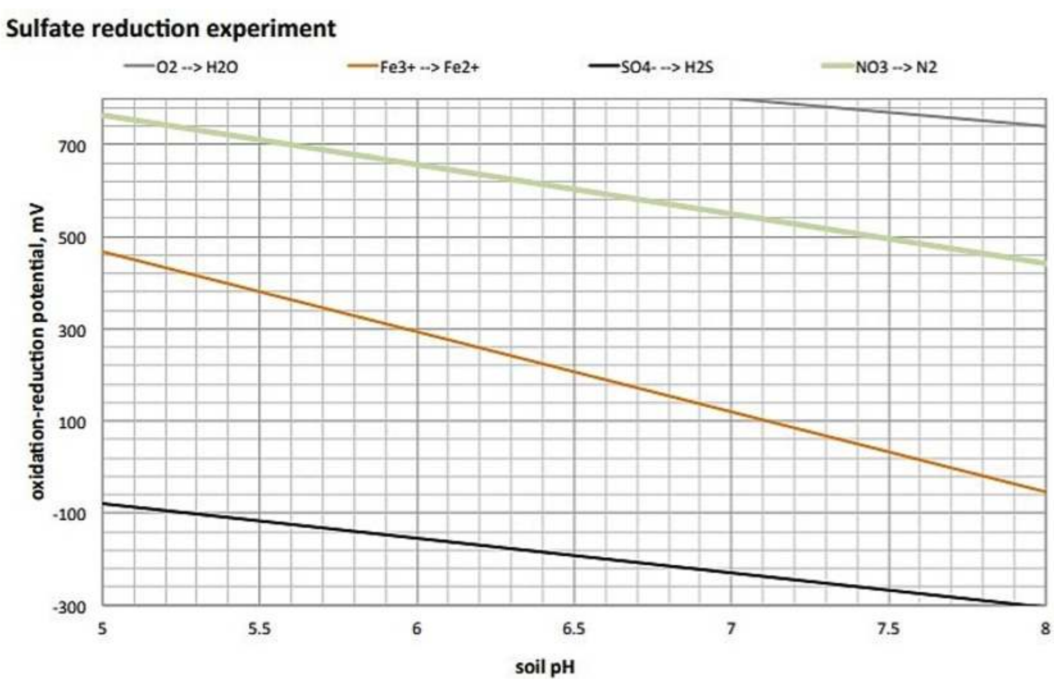



Figure 9. Redox diagram demonstrating the function of pH and redox potential on the fate of reduction for various chemical compounds. The upper right of a redox diagram represents highly oxidized conditions, while the lower left represents highly reduced conditions, by Vaughan & Duball, 2019.

## Effects of reducing soil conditions on the soil environment

Anaerobic conditions can generate methane gas. The gas may be visible as entrapped bubbles in the suspension. Also, the anaerobic conditions can be appreciated by carefully detecting the nature of the system using your olfactory senses (smell). Under anaerobic conditions, microorganisms are prone to generate many organic amines (such as putrescine), which are highly odoriferous. Hydrogen sulfide (rotten egg) gas can be generated when the system becomes strongly anaerobic and most of the metal ions have been converted to FeS or $FeS_2$.

Sulfate reduction occurs under anaerobic conditions where the sulfate ion serves as an alternate electron acceptor replacing the normal oxygen gas molecule. Energy must be provided to the microorganisms in the form of readily available organic material, which provides the electrons in the H atoms that are never isolated as such in the reaction. The reaction may be summarized as follows:

$$SO_4^2 + 8[H^+] \rightarrow S^{2-} + 4H_2O$$

The sulfide that forms is very reactive. It forms extremely insoluble metal sulfides (iron-monosulfides (FeS) and pyrites ($FeS_2$)). These metal sulfides give the solution a black or dark gray appearance. Often an organic mat forms on the surface of these soils.

*Please read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

---

# 7.2: Activity 1 - Soil Colloids

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

*1) Fill in the blanks regarding characteristic properties of soil colloids.*

| **Soil Colloid Type** | **Name one defining characteristic of this colloid** | **Where in the soil profile will these colloids dominate?** | **What soil order would contain a large amount of these colloids?** |
|---|---|---|---|
| Crystalline silicate clay (1:1) | | | |
| Crystalline silicate clay (2:1) | | | |
| Noncrystalline silicate clay | | | |
| Fe and Al Oxides | | | |
| Humus | | | |

*2) Describe the major difference between a 1:1 silicate clay and a 2:1 silicate clay.*

# 7.3: Activity 2 - Soil Charge

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

1) The instructor has set out two samples of the same soil and placed them into leaching tubes. Into one tube the instructor will add a solution of Eosine Yellow. Eosine Yellow is a complex organic dye with a negative electrical charge, making it an anion. Into the other tube the instructor will add a solution of Methylene Blue. Methylene Blue is a complex organic dye with a positive electrical charge, making it a cation. A sufficient amount of solution will be added to allow the accumulation of about 50 mL of leachate. Observe the color of the resulting soil in each tube and the color of leachate that came through each sample of the same soil. Record your observations in the table.

| | Eosine Yellow | Methylene Blue |
|---|---|---|
| Color of the soil | | |
| Color of the leachate solution | | |
| Electrical charge on the dye | | |

<u>*CEC experiment questions:*</u>

1. *Which dye leached through the soil and into the leachate?*
2. *What can you conclude will probably happen with other similar ions with the same electrical charge as this dye when added to the soil as fertilizers or spilled accidentally onto the soil followed by a heavy rain or water (as from irrigation or a fire truck to disperse a toxic spill of this ion)?*
3. *Which dye remained attached to the soil and consequently colored the soil?*
4. *What can you conclude will probably happen with other similar ions with the same electrical charge as this dye when added to the soil as fertilizers or spilled accidentally onto the soil followed by a heavy rain or water (as from irrigation or a fire truck to disperse a toxic spill of this ion)?*
5. *What is the name of the process demonstrated by this experiment?*

# 7.4: Activity 3 - Soil Charge Calculations

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

1. *A prairie soil contains 30% clay. This clay-sized fraction is dominantly montmorillonite. The soil also contains 5% humus (organic matter).*

    *a. Using the mineralogy method, what is the cation exchange capacity (CEC) contributed by the clay?*

    *b. What is the estimated cation exchange capacity (CEC) contributed by the humus?*

    *c. What is the total estimated CEC of this soil?*

    *The following is actual laboratory data for the soil in the example:*

| Exchangeable Acidity | Exchangeable Bases | | | |
|---|---|---|---|---|
| $H^+ + A1^{3+}$ | $Ca^{2+}$ | $Mg^{2+}$ | $K^+$ | $Na^+$ |
| ---- $cmol_c/kg$ ---- | | ---- $cmol_c/kg$ ---- | | |
| 14.0 | 29.0 | 10.0 | 5.5 | 1.5 |

    *d. Calculate the CEC from the data in the table using the sum of cations method.*

# 7.5: Activity 4 - Soil pH and Electrical Conductivity

Name: _______________________________

Section: ______________________________

Student ID#:___________________________

## 1) Measuring pH:

a. Add 5 g of each soil type into to sterile cup.

b. Add 20 mL of DI water

c. Mix the soil and water until it is a uniform slurry

d. Use pH meter and place electrode into the slurry

e. Wait until the reading stabilize

f. Record pH

g. Rinse and wipe down meter

h. Repeat process for all samples

pH Data-

| Sample ID | pH |
| --- | --- |
| | |
| | |
| | |

## 2) Measuring EC:

(Follow procedure for measuring pH)

EC Data-

| Sample ID | EC |
| --- | --- |
| | |
| | |
| | |

### pH and EC questions:

1. *Which soil sample had the highest pH? Lowest?*
2. *What range of salinity does each soil sample meet?*
3. *If your soil had a pH of 5 what treatment needs to be done so that alfalfa can be planted?*
4. *What is the pH range for All Textures for Slightly Saline?*

# 7.6: Activity 5 - Reduction and Oxidation Reactions

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

*Your instructor has prepared a set out a suite of mesocosms, which have been incubating since the beginning of the semester with some under fully saturated conditions and some under aerobic conditions, representing* two different reduction samples.

The objective of this experiment is to evaluate the redox potential (Eh) and the pH of the soil solutions that were incubated with an aerobic or an anaerobic condition during the semester.

*You will conduct the following:*

1. *OLFACTORY OBSERVATIONS…*
   - Carefully open the lid of the sulfate reduction jar. Do not shake or agitate the suspension.
   - Hold the jar in front of your face and use your hand to waft the air towards your nose. Smell the gases being released.
   - Record the nature of your observations.
   - OBSERVATIONS →
2. *SOIL pH MEASUREMENTS…*
   - Carefully insert the pH electrodes into the suspension in the container.
   - Measure the pH of each suspension. It will take about 20 seconds for the pH meter to stabilize each system.
   - Record the pH values for each system.

| | |
|---|---|
| pH Measurements for → | Control: |
| | Organic Matter Addition |
| | $K_2SO_4$ Addition: |
| | OM+$K_2SO_4$: |

*In addition, your instructor has set out another suite of mesocosm experiments with indicator of reduction in soil (IRIS) tubes inserted into the soil for one month. Protocol for interpreting IRIS tubes is also on display for you to review. After interpreting the IRIS tubes please answer the following questions below:*

1. Which mesocosms displayed reduction of sulfate?
2. How do you know sulfate was reduced? Please describe in detail below including the chemical reaction involved.
3. What colors indicate reduction of iron? __________________ and ________________.
4. When iron (Fe) is reduced it goes from ____________ to ___________. (form of iron)
5. Reduction of what chemical compound exemplifies the strongest reducing soil conditions? (State the oxidized and reduced forms)
6. Refer to Figure 11 to answer the following questions.
   - At the following Redox Potential (Eh) in Mv, and pH ranges, what compounds are being reduced?
     - Eh = +400, pH = 8 → ____________
     - Eh = 0, pH = 6 → ____________
     - Eh = -300, pH = 5 → _____________
   - Who is responsible for the microbially mediated reactions at the following ranges?
     - Eh = +500, pH = 9 → ____________________
     - Eh = 0, pH = 9 → _____________________

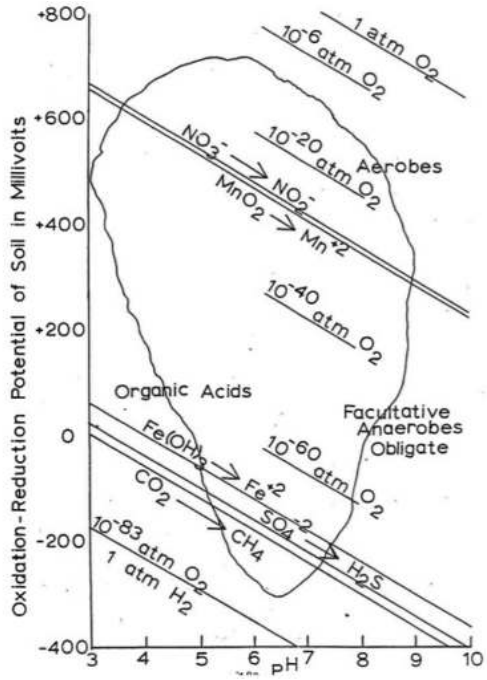



Figure 1: “Schematic of process for determining cation exchange capacity” by Colby J. Moorberg and David A. Crouse is licensed under CC by 4.0

# CHAPTER OVERVIEW

## 8: Soil Health & Quality

**Learning Objectives**

- Define soil health.
- Understand the difference between inherent and dynamic soil properties/qualities.
- Become familiar with the nutrient cycles of nitrogen, potassium and phosphorus and the carbon cycle.
- Identify how different soil management strategies can affect nutrient cycling.
- Solve fertilizer calculations for given scenarios.

**GOAL**: To become familiar with the importance of the many aspects of soil health and understand it as the capacity of soil to function as a vital living ecosystem.



**Additional resources**:

- USDA NRCS Soil Quality Test Kit https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment/?cid=nrcs142p2_053873
- NRCS employee Ray Archuleta preforming slake test and infiltration test https://www.youtube.com/watch?v=CEOyC_tGH64 (video length 7:09)

# 8.1: Introduction to Soil Health

## Introduction to Soil Health

(Adapted from NRCS, 2017)

Soil health is also commonly referred to as, soil quality. As defined by the Natural Resource Conservation Service, soil health is "the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans." This concept identifies the fact that only "living" things can have health, thereby stressing the concept that a **soil is a living ecosystem**. As with all living entities, including living ecosystems, the only way to maintain life is through proper management.

Soil is not simply an inert growing medium, but rather it is comprised of billions of biological organisms, ranging from microscopic to macroscopic in size. Together these organisms help to maintain the life of the soil, as well as many physical, chemical and biological factors. Therefore, soil is an ecosystem which can provide the following capabilities: (NRCS, 2017)

1. **Regulating water** - Soil helps control where rain, snowmelt, and irrigation water goes. Water and dissolved solutes flow over the land or into and through the soil.
2. **Sustaining plant and animal life** - The diversity and productivity of living things depends on soil.
3. **Filtering and buffering potential pol utants** - The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits.
4. **Cycling nutrients** - Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled in the soil.
5. **Physical stability and support** - Soil structure provides a medium for plant roots. Soils also provide support for human structures and protection for archeological treasures.

The capabilities of a soil are determined by both inherent and dynamic properties/qualities within the soil. **Inherent soil quality** is, "a soil's natural ability to function." An example of an inherent soil property/quality is how a sandy texture soil drains faster than a clayey texture soil, or how a deep soil has more space for root growth compared to a soil with bedrock at or near the surface. Essentially the idea behind inherent properties/qualities is that these characteristics do not change easily. On the contrary, **dynamic soil quality** is, "how soil changes depending on how it is managed." Management decisions and efforts can affect factors such as the amount of soil organic matter, soil structure, and water and nutrient holding capacity. Thus, dynamic soil quality is directly affected by inherent soil quality.

One major goal of soil health is to manage the soil in a way that enhances or improves soil function. It is important to understand that soils wil respond differently to management depending on inherent soil properties, and so how these properties vary across the surrounding landscape should be taken into consideration. Another core goal of soil health is to assess and manage soil so that it functions optimal y for current and future use. Monitoring changes in soil health is critical for determining sustainable soil management and practices.

## Aggregate Stability

A soil with strong aggregates generally has adequate biological activity, organic matter, and nutrient cycling present. When soil aggregates are weak, it may be a sign of degradation.

Leaving soil vulnerable to greater risk of wind and water erosion, and impeding infiltration and root growth. Aggregation is especially important for survival of biological soil communities and will affect the amount of pore space between the soil particles, therefore also impacting bulk density, CEC, and many other dynamic soil properties.

Soil particles form aggregates as a product of cementing agents in the soil including clay content, adsorbed cations such as calcium and magnesium, and iron oxide content. Expansion and contraction of clay particles as they become moist and then dry can shift and crack the soil mass and create aggregates or break them apart. Calcium, magnesium, iron, and aluminum stabilize aggregates via organic matter sorption. In contrast, aggregate stability decreases with increasing amounts of exchangeable sodium: dispersion is promoted when too many sodium ions accumulate between soil particles.

Tilling a soil can both promote and destroy soil aggregates. If the soil is at an appropriate moisture level, tillage can break large clods into natural aggregates, creating a loose, porous condition that is conducive to the growth of young roots and seedlings, as well as incorporating organic amendments into the soil and killing weeds. However, over many years, tilling practices can increase the oxidative loss of soil organic matter, weakening soil aggregates. If tillage is carried out when soil is too wet, soil aggregates can be crushed or smeared, resulting decreased macro porosity and creation of ponding conditions.

One method to determine if a soil has stable aggregates is to perform a slaking test, which is recommended by the USDA Natural Resources Conservation Service.

## NUTRIENT CYCLING

There are several plant-available nutrients that are important to the overall health of a soil. The three major nutrients of importance are N, P, and K. Nutrients occur naturally in soils in mineral form, through biological inputs, atmospheric deposition, and the application of fertilizers. Nutrients are lost from systems through processes like runoff, water solubility, plant uptake and leaching. When managing a soil for plant production, it is important to understand nutrient cycles, availability, and potential for loss.

### The Nitrogen Cycle

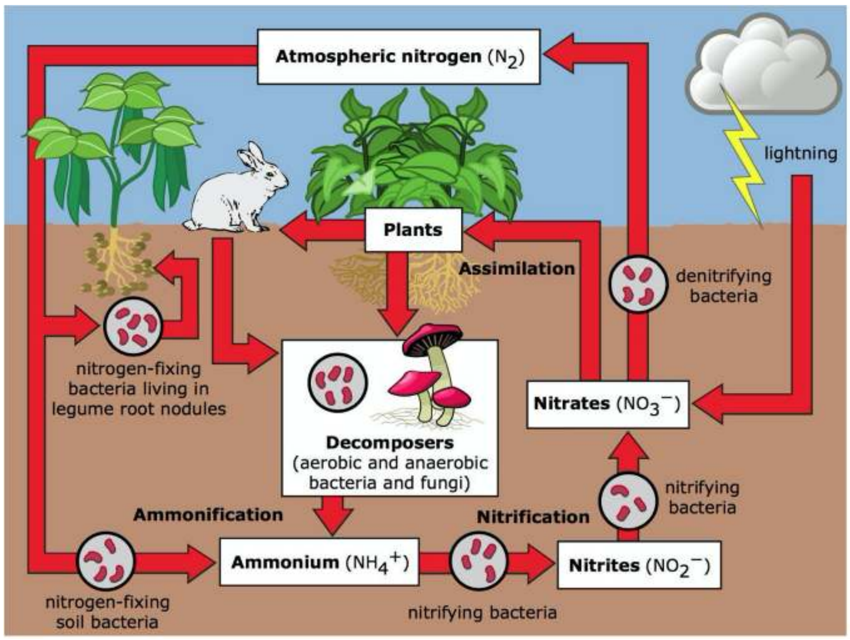



Figure 1: The Nitrogen Cycle by Johann Dréo, CC BY-SA 3.0

**Nitrification** is the oxidation of reduced forms of N, typically ammonium ($NH_4^+$), via nitrite ($NO_2$), to nitrate ($NO_3^-$). The process begins with autotrophic and chemolithotrophic bacteria oxidizing ammonium generated by organic matter mineralization and fertilizer addition, producing nitrate and acid, leading to soil acidification. The process of nitrification determines the relative amounts of different inorganic N sources available for plant and crop growth and is responsible for significant loss of added N fertilizer.

**Denitrification** involves the reduction of nitrate to nitrite, nitric oxide, nitrous oxide and nitrogen gas. This process is catalyzed by bacteria, archaea and fungi, and is essential for returning N to the atmosphere.

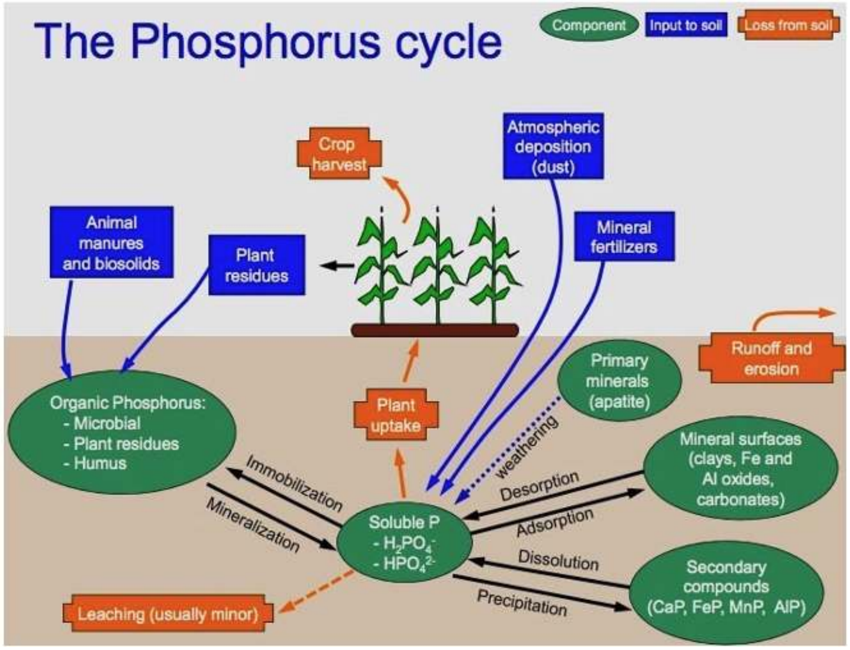



Figure 2: The P Cycle Welcome1To1The1Jungle at English Wikipedia, Phosphorus Cycle copy, CC BY 3.0

Compared to other macronutrients, like S and Ca, the concentration of **phosphorus** in the soil solution is very low, generally ranging from 0.001 mg/L in infertile soil to 1 mg/L in heavily fertilized soils. Plant roots absorb P dissolved in soil solution, mainly as phosphate ions ($HPO_4^{2-}$ and $H_2PO_4$ ), determined by the soil pH. In strongly acid soils (pH 4 5.5), $H_2PO_4^{2-}$ dominates, while alkaline soils contain mostly $HPO_4^{2-}$. Phosphorus is lost from the soil by plant removal, erosion of P-carrying soil particles, P dissolved in surface runoff water and leaching to groundwater. Additions of P to the soil from the atmosphere are smal but may balance losses in undisturbed ecosystems. For optimal crop production, input from fertilizer to exceed the removal in crop harvest may be required. Phosphorus held in organic forms can be **mineralized** and **immobilized** by the same general processes that release N and C from SOM: immobilization and mineralization. [1] These processes are influenced by the same factors that control general decomposition of SOM: temperature, moisture, and tillage.

[1] Net immobilization of soluble P is likely to occur if residues added to the soil have a C/P ratio that is greater than 300:1, while net mineralization is likely if the ratio is below 200:1.

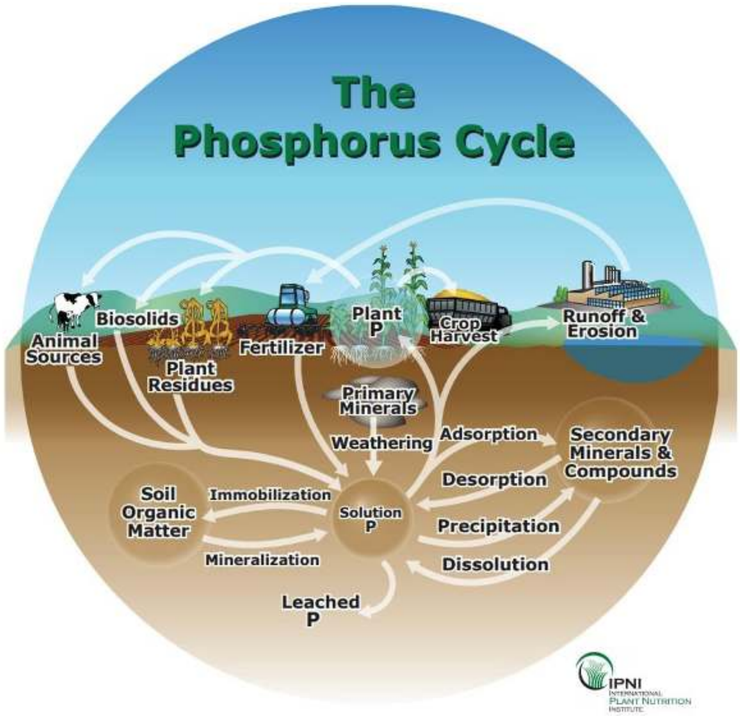



Figure 3: The Potassium Cycle

In contrast to phosphorus, **potassium** is found in comparatively high levels in most mineral soils, yet the quantity of K held in an easily exchangeable condition is often very small. However, over time K can be released to exchangeable and dissolved forms in the soil solution and can be quickly taken up by plants.

Potassium is readily lost by leaching, which can be reduced by increasing the cation exchange capacity (CEC) of the soil.[2] Liming an acidic soil to raise pH can reduce the leaching losses as wel . Plants take up very large amounts of K so biomass removal is another source of K loss from soils. This situation is increased by **luxury consumption**, or the tendency of plants to take up soluble potassium in excess if sufficiently large quantities are present.

[2] CEC is the attraction of positively charged potassium ions to the negatively charged cation exchange sites on clay and organic matter.

Forms of potassium in soils, as shown in the graphic above, include K in primary mineral structure (unavailable to plant uptake), nonexchangeable K in secondary minerals & compounds (slowly available), and exchangeable K+ on soil colloids and K2O soluble in water (readily available, only 1-2% of total soil potassium).

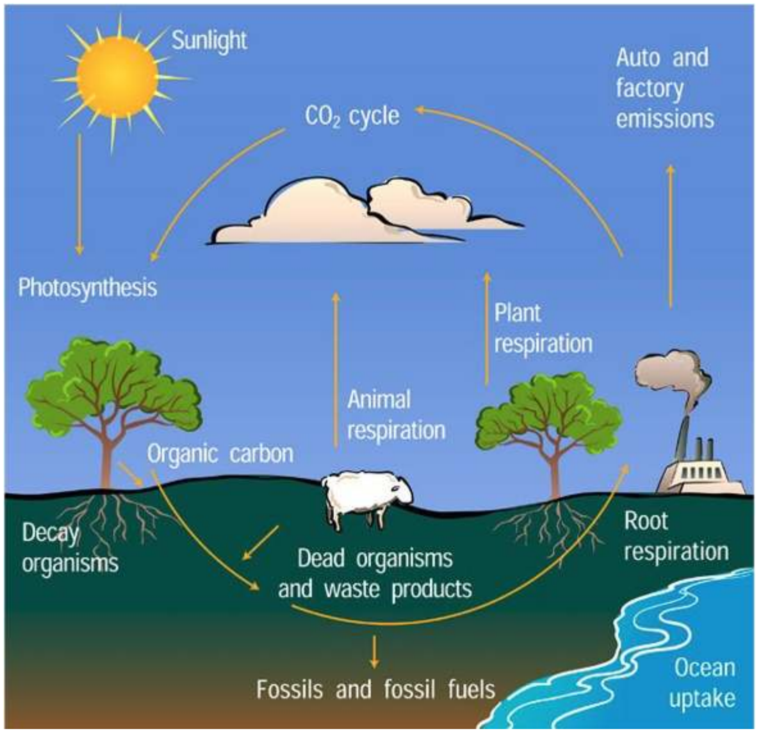



Figure 4: *"The Carbon Cycle" by University Corporation for Atmospheric Research*

The **carbon cycle** illustrates the role of soil in the global C cycle. There is more C stored in soil than in the atmosphere and above-ground biomass combined! Soil C is in the form of organic compounds originally created through photosynthesis, in which plants convert atmospheric $CO_2$ into plant matter, and enter the soil system as plants and animals die and decompose. Soil organisms consume the organic matter extracting energy and nutrients and releasing water, heat, and $CO_2$ back into the atmosphere. If organic matter is added to the soil at a faster rate than organisms convert it to $CO_2$, C will gradually be removed from the atmosphere and sequestered in the soil.

Cultivation aerates the soil, triggering increased biological activity, and therefore rapid decomposition, loss of SOM and the release of $CO_2$ into the atmosphere. Most soil C losses occur in the first several years after cultivation begins, and currently farmers and scientists are interested in reversing that effect by increasing C stored in the soils through management. (Source: NRCS East National Technology Support Center)

## NUTRIENT AVAILABILITY

In addition to nutrient cycling, the actual availability of those nutrients to the plants is critical to consider when assessing soil health. Certain nutrients are only available under specific soil conditions. Soil pH is especially important when it comes to nutrient availability. Consider the following figure:

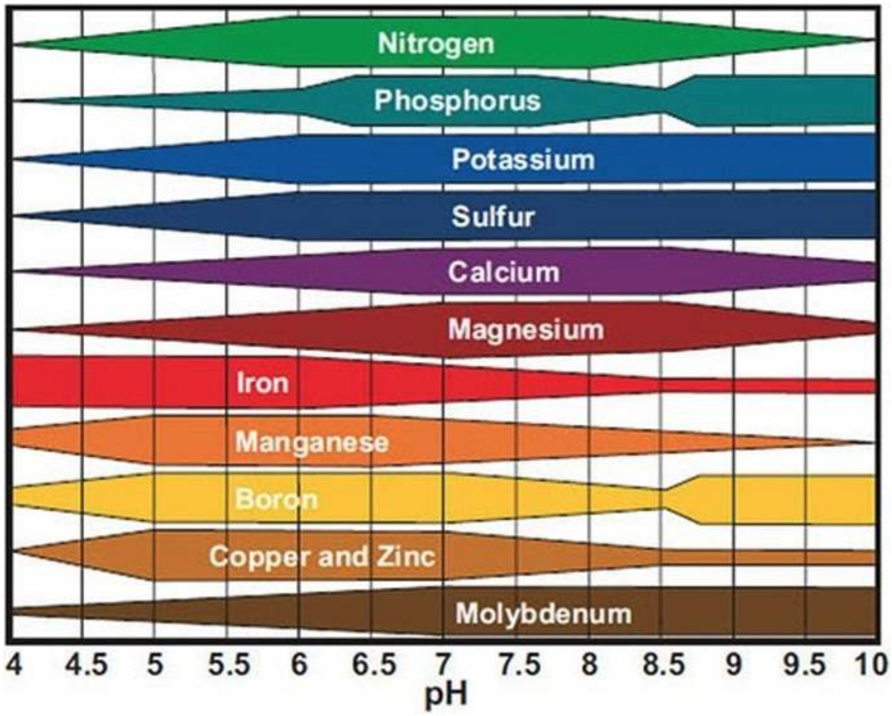



Figure 5: Nutrient availability (Source: Rough Brothers Inc.)

The width of the bar indicates the relative range of availability for each nutrient at various pH levels. Thicker bar widths reflect increased availability, and thinner sections of the bar reflect conditions at which nutrient availability is decreased.

*Read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

---

# 8.2: Activity 1 - Aggregate Stability

**Slake Test**

1. Carefully select one in-tact soil aggregate from the available soil.
2. Place the soil aggregate on the sieve.
3. Fill the beaker with approximately 1.5 inches of water, or so that the soil aggregate will be just immersed in water when lowered into the beaker.
4. Lower the sieve into the beaker of water. Observe the soil aggregate for 5 minutes and keep track of the timing of structural loss. Refer to the stability class table below to determine class 1 and 2.
5. Once stability class 1 and 2 are determined, raise the sieve + aggregate out of the water for one second, and immerse again for another second.
6. Repeat immersion 4 times. Refer to the stability class table below to determine and record stability classes 3 through 6.

Table 1. Stability class table (Source: USDA NRCS Soil Quality Test Kit)

| Stability class | Criteria for assignment to stability class (for "Standard Characterization") |
|---|---|
| 0 | Soil too unstable to sample (falls through sieve). |
| 1 | **50 %** of structural integrity lost within **5 seconds** of insertion in water. |
| 2 | **50 %** of structural integrity lost **5 - 30 seconds** after insertion. |
| 3 | **50 %** of structural integrity lost **30 - 300 seconds** after insertion or **< 10 %** of soil remains on the sieve after 5 dipping cycles. |
| 4 | **10 - 25%** of soil remaining on sieve after 5 dipping cycles. |
| 5 | **25 - 75%** of soil remaining on sieve after 5 dipping cycles. |
| 6 | **75 - 100%** of soil remaining on sieve after 5 dipping cycles. |

**Questions**

1. Aggregates of soils high in organic matter are more stable than are those low in OM. Which soil aggregates fall apart when wetted, and which will maintain their stability?
2. Discuss the positive and negative impacts of tillage on soil structure. What is a physical consideration in deciding whether to utilize this practice on agricultural land?
3. What are 3 management strategies to support and promote soil aggregation?

# 8.3: Activity 2- Nutrient Cycling and Availability

*Fill in the following information pertaining to the nutrient cycles provided previously-*

| Nutrient Cycle | Nutrient Inputs | Nutrient Losses | Is weathering a factor? (Y/N) | Is soil organic matter a factor? (Y/N) | Name the plant-available form |
|---|---|---|---|---|---|
| N | | | | | |
| P | | | | | |
| K | | | | | |

1. How does CEC affect the cycling processes of P and K?
2. Name one soil management strategy used to decrease the following scenarios:
   1. Volatilization of N:
   2. Runoff of P inputs from manure:
   3. Leaching of N, P, or K:
3. How does nutrient cycling contribute to overall “soil health”?
4. What are two techniques to increase soil C sequestration?
5. Name two techniques to reduce P losses to water.
6. Which soil, a sandy loam or clay loam, would have a larger buffering capacity for potassium? Why?

*Fill in the following information pertaining nutrient availability and pH*

| Nutrient | pH range most available | pH range least available |
|---|---|---|
| N | | |
| P | | |
| K | | |
| S | | |
| Fe | | |
| Ca | | |

# 8.4: Activity 3 - Soil Nitrate

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

Source: NRCS Soil Quality Test Kit Guide, Ch 7

## At home before lab:

1. Collect approximately ½ cup of soil from a garden or farm. Make sure to sample only to a 0-3inch depth. To collect a representative sample, collect three samples across the field to capture variability. Determine the texture of your soil sample and record it.

## Materials needed to measure soil nitrate:

- 1/8 cup soil collected by student prior to lab
- Filter paper
- 120-mL plastic container with lid
- Eye dropper
- Nitrate/nitrite test strips
- Stopwatch or timer
- Distilled water

## Procedure (in lab)

1. Familiarize yourself with the directions on the side of the bottle of nitrate strips.
2. Prepare soil-water sample
    1. Thoroughly mix soil sample before taking 2 tablespoon sub-sample and placing in plastic container. Record weight of subsample.
    2. Add 30 mL of distilled water to the soil subsample, creating a 1:1 soil to water ration on a volume basis
    3. Put the lid on the container and shake vigorously 25 times.
3. Fold filter paper in half (semi-circle), the fold again into a quarter-circle.
4. Insert filter paper into subsample
    1. Open filter paper into a cone shape and push it quickly into the container with the soilwater mixture until it touches the bottom of the container. Wait for an eye dropper-full of the solution has seeped through to the inside of the filter paper.
5. Place drops on Nitrate Strips
    1. Using the eye dropper and one nitrate/nitrite test strip, place 1 or 2 drops of the filtered solution on each of the strip's two pads. **Note the time**.
    2. **Note**: one pad measures the amount of nitrite and the other measures the amount of nitrite and nitrate combined. Nitrite rarely occurs in measurable amounts in the soils, so nitrite readings from the test strips are not recorded.
6. Measure and record nitrate
    1. Align the nitrate/nitrite test strip with the bottom of the bottle with your thumb corresponding to the diagram on the bottle.
    2. After 60 seconds, compare the first pad furthest from your thumb) along the nitrate scale and estimate the amount according to the degree of color change. Record that value on the worksheet in ppm. This is an estimate of the nitrate-N concentration in the solution.

**Calculations:**

**Estimated** (lb $NO_3$-N/acre)=

$$\frac{(\text{ppm extract } NO_3 - N) \times (\text{depth of soil sampled in cm}) \times \text{bulk density} \times 0.89}{10}$$

**Exact** (lb $NO_3$-N/acre)=

$$\frac{(\text{ppm } NO_3 - N) \times (\text{volume water used}) \times (\text{depth of soil sampled, cm}) \times \text{bulk density} \times 0.89}{(\text{dry weight of soil}) \times 10}$$

Volume of water used = 30mL + [dry weight of soil x soil water content (g/g)]

**ppm in extract = lb $NO_3$-N/acre / 43.6 = lbs/1000 sq ft

**Note:** for garden topsoil, bulk density can be assumed to be 1.1 g/cm$^3$ and 1.5 g/cm$^3$ for subsoil. For all other soil textures, see table below.

Table 1. Soil bulk density according to texture

| *Soil Textures* | *Avg bulk density (g/cm3)* |
|---|---|
| *Organic matter* | *0.22* |
| *Sand* | *1.56* |
| *Loamy sand* | *1.54* |
| *Sandy loam* | *1.5* |
| *Loamy sand* | *1.45* |
| *Silt loam* | *1.2* |
| *Sandy clay loam* | *1.63* |
| *Silty clay* | *1.55* |
| *Clay loam* | *1.45* |
| *Silty clay loam* | *1.4* |

**Note:** The maximum nitrate-N reading on the nitrate/nitrite test strip container is 50 ppm. If the sample reading falls into the 50 ppm category, the sample can be diluted to get a better estimate of the actual amount over 50 ppm. To dilute the sample, fill the eye dropper with filtered solution and place five drops in a plastic container. Add five drops of distilled water; mix gently by swirling the container. Take a reading with a new test strip as stated in Step 4. Multiply the estimated nitrate-N in ppm by 2 before using the calculations. If the nitrate reading falls into the category of 50 ppm again, repeat the dilution steps, and multiply the estimated nitrate-N in ppm by 4.

| | |
|---|---|
| Soil sample site description | |
| Soil sample texture | |
| Bulk Density | |
| Soil $NO_3$-N ppm (est.) | |
| Estimated Soil $NO_3$-N (lb $NO_3$-N/acre) | |
| Exact Soil $NO_3$-N (lb $NO_3$-N/acre) | |

## N-Availability Questions

1. Using Table 2, determine three vegetables that would have soil-N requirements met based on your soil sample.
2. Compost might typically contain about 1% total N, but only 10% of that becomes available in the first year. So typical compost would contain 0.1% $NO_3$-N, meaning about 1000 lb of compost is needed for each lb of N to be added, and substantially increase SOM content. Explain how compost can provide a supply a slow release of nutrients and long-term benefits to soil health.

Table 2. Nutrient requirements of common vegetables

| Nutrient requirements of common vegetables | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Vegetable | Nitrogen (N) | | | Phosphorus (P) | | | Potassium (K) | | |
| | High | Med | Low | High | Med | Low | High | Med | Low |
| Asparagus | x | | | | x | | x | | |
| Beans | | | x | | | x | | | x |
| Beets | | x | | | x | | | x | |
| Broccoli | | x | | x | | | x | | |
| Brussels Sprouts | | x | | x | | | x | | |
| Cabbage | | x | | x | | | x | | |
| Carrots | | x | | x | | | x | | |
| Cauliflower | | x | | | x | | | x | |
| Celery | x | | | x | | | x | | |
| Corn | | x | | x | | | | x | |
| Cucumbers | | x | | | x | | | x | |
| Eggplant | | x | | x | | | x | | |
| Horseradish | | x | | | x | | | x | |
| Kale | | x | | x | | | x | | |
| Lettuce | | x | | | x | | | x | |
| Onions | | x | | | x | | | x | |
| Parsnips | | x | | | x | | | x | |
| Peas | | | x | | | x | | | x |
| Peppers | | x | | x | | | x | | |
| Potatoes | | x | | x | | | x | | |
| Pumpkins | | x | | x | | | x | | |
| Radishes | | x | | | x | | | x | |
| Rutabaga | | | x | | x | | | x | |
| Squashes | | x | | x | | | x | | |
| Swiss Chard | | x | | | x | | | x | |
| Tomatoes | | x | | x | | | x | | |
| Turnips | | x | | | x | | | x | |

| Soil nutrient required for veggies with high, medium, and low requirements: | Nitrogen (N) | Phosphorus (P) | Potassium (K) |
|---|---|---|---|
| High (H) | > 1.5kg per 100m sq | > 0.4kg per 100m sq | > 2.0kg per 100m sq |
| Medium (M) | 0.5-1.5kg per 100m sq | 0.2-0.4kg per 100m sq | 1.0-2.0kg per 100m sq |
| Low (L) | < 0.5kg per 100 m sq | <0.2kg per 100 m sq | < 1.0kg per 100 m sq |
| **High (H)** | **> 3 lbs per 1000 sq ft.** | **> 0.8 lbs per 1000 sq ft.** | **> 4 lbs per 1000 sq ft.** |
| **Medium (M)** | **1-3 lbs per 1000 sq ft.** | **0.4-0.8 lbs per 1000 sq ft.** | **2-4 lbs per 1000 sq ft.** |
| **Low (L)** | **< 1 lb per 1000 sq ft.** | **< 0.2 lbs per 1000 sq ft.** | **< 2 lbs per 1000 sq ft.** |

## 8.5: Activity 4 - Fertilizer Calculations

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

Additions of fertilizer are important for maintain ideal soil health in agricultural management. Please complete these calculations to determine the amount of N, P and K in fertilizers.

The following conversion factors and units equivalencies will be useful to complete the fertilizer problems.

- lb P = lb $P_2O_5$ × 0.44
- lb $P_2O_5$ = lb P × 2.29
- lb K = lb $K_2O$ × 0.83
- lb $K_2O$ = lb K × 1.21
- 1 ton = 2000 lb
- 1 ac = 43,560 $ft^2$

### Determining the amount of N, P, K in fertilizers

You have a 50 lb bag of granular fertilizer with a label that reads 15-10-10. The grade is 15-10-10, which is the percentage by weight of N, P as $P_2O_5$, and K as $K_2O$. This fertilizer contains 15% by weight N, 10% by weight $P_2O_5$, and 10% by weight $K_2O$. We want to know the following:

1. How many lbs of N are in the bag? Of the 50 lb of fertilizer in the bag, we know that 15% of that is N. How many lbs of $P_2O_5$ are in the bag? How many lbs of $K_2O$?
2. How many lb of P are in the bag?
3. How many lb of K are in the bag?

#### Calculate:

1. How much N is in a 50 lb bag of 12-22-18?
2. How much $P_2O_5$ is in a 40 lb bag of 0-46-0?
3. How much $K_2O$ is in a 70 lb bag of 12-22-18?
4. How much N is in a 30 lb bag of 0-46-0?
5. How much N is in a ton of DAP (18-46-0)?
6. How much P is in a ton of DAP (18-46-0)?

### Calculating the amount of fertilizer needed to supply a certain amount of N, $P_2O_5$, or $K_2O$.

When we calculate the amount of fertilizer needed to supply a certain amount of N, $P_2O_5$, or $K_2O$ we need to know:

1. How much N, $P_2O_5$, or $K_2O$ is needed per unit area (e.g., 1,000 square feet, acre, etc.)
2. The analysis (grade) of the fertilizer (e.g., 10-10-10, 0-46-0, etc.)
3. How much area we need to fertilize.
4. For manure applications, you need to know the amount of N that will be available during the growing season. Rule of thumb is 60%.

You need to apply 2 lbs of N per 1,000 square feet. You have a 30-0-0 grade fertilizer available for application. The area you need to fertilize is 150,000 square feet. How much fertilizer do you need to apply?

*Step 1. Determine the rate of fertilizer needed.*

*Step 2. Determine the fertilizer analysis (grade).*

*Step 3. Calculate how much fertilizer you need per 1,000 square feet.*

Divide the fertilizer application rate by 0.30 (30%):

*Step 4. Calculate how much fertilizer is needed to cover the required area.*

We need to fertilize a total of 150,000 square feet (given in the problem), which means that we multiply by the amount of fertilizer needed to apply 2 lb N to 1000 sq ft. by 150. (Note: 150 comes from dividing 150,000 sq ft/1000 sq ft):

### Calculate:

1. You need to apply 2 lbs of N per 1,000 square feet. You have a 15-10-10 fertilizer available, and the total area to be fertilized is 3 acres. How much fertilizer will you need? (Hint: Don't forget to convert sq. ft. to acres!)

---

# CHAPTER OVERVIEW

## 9: Field Lab

**Learning Objectives**

- Know and understand the five soil-forming factors and how they influence the formation of local soils.
- In the field, determine the soil properties of texture, structure, color, pH, slope %, slope position, water runoff class, and water permeability.
- Learn the major properties of cambic, calcic, and argillic diagnostic horizons.

**GOAL**: To perform a soil morphological description in the field



**Additional resources**:

- Field Book for Describing and Sampling soils (aka the RED BOOK) https://www.nrcs.usda.gov/Internet/F...2p2_052523.pdf
- Soil data explorer available from UC Davis https://casoilresource.lawr.ucdavis.edu/gmap/

# 9.1: OVERVIEW

Soils occur in definite patterns as a consequence of the five soil-forming factors. Short distance changes in the soils are related primarily to changes in topography and parent material.

# 9.2: Climate

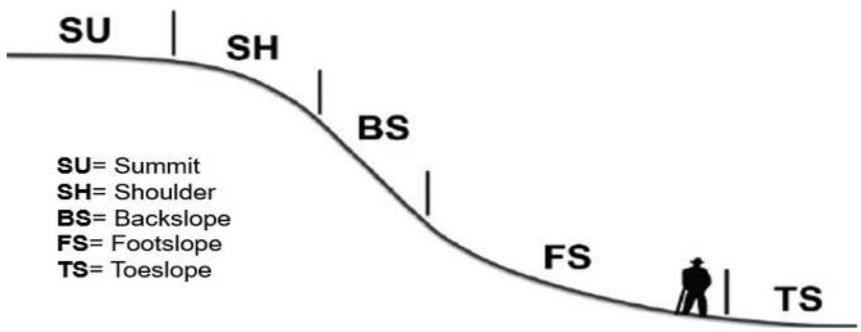
Climate as a soil-forming factor helps determine soil differences on a regional scale (e.g. arid desert vs. humid forest ecosystem) or on a local level (micro-climatic differences). The important components of climate influencing soil formation include precipitation and temperature. As precipitation increases from one locale to another, more water is available to move downward through the soil profile. As water percolates downward (called leaching), water-soluble soil constituents such as soluble salts (bicarbonates, chlorides, nitrates) are translocated from upper soil horizons and are moved deeper into the soil profile.

Other materials including clay minerals do not dissolve in water, but the clay particles can be suspended in the soil solution and may leach into subsoil horizons. The greater the amount of precipitation, the deeper these dissolved and suspended materials are leached. The consequences of leaching include a lower pH (greater acidity), fewer basic cations ($Ca^{2+}$, $Mg^{2+}$, $K^+$, $Na^+$), and a lower nutrient content. As a result of variations in rainfall, little leaching occurs in desert soils while extensive leaching occurs in humid forest soils.

Soil temperature regulates the amount of evapotranspiration. The higher the temperature, the greater the amount of evapotranspiration. In hot, dry regions, any precipitation (rainfall) added to the soil may quickly evaporate into the atmosphere. In cool, moist regions, precipitation accumulates in the soil and leaching results. If two regions have the same amount of precipitation, the region having the lower soil temperatures will have more "effective" precipitation and soils will be more highly leached in the cooler region. On a local scale in the Northern Hemisphere, this concept explains the differences between soils on north-facing slopes compared with those on south-facing slopes. The soils on the north-facing slopes receive less direct solar radiation (lower temperatures, less evaporation). These soils on north-facing slopes are more highly weathered, deeper, and subject to greater leaching than are the soils on the south-facing slopes where the microclimate is warmer and drier.

| **Temperature regimes:** | **Moisture regimes:** |
|---|---|
| *Gelic:* < 0 $^oC$ | *Aquic:* (or Perudic): Saturated with water long enough to cause oxygen depletion |
| *Cryic:* 0-8 $^oC$ (cold summers) | *Udic:* Humid or subhumid climate |
| *Frigid:* 0-8 $^oC$ (warm summers) | *Ustic:* Semiarid climate |
| *Mesic:* 8-15 $^oC$ | *Aridic* (or Torric): Arid climate |
| *Thermic:* 15-22 $^oC$ | *Xeric:* Mediterranean climate (cool, moist winters and warm, dry summers) |
| *Hyperthermic:* >22 $^oC$ | |

## 9.3: Relief




Hillslope positions across a landscape Wysocki et al., 2000 and Schoeneberger et al., 2012

| | |
|---|---|
| Summit | The top or highest level of an upland feature such as a hill or mountain. Usually, the summit is relatively level. |
| Shoulder | Forms the uppermost inclined surface at the top of a hill slope. It is the transition zone from the summit to the backslope of an upland. The surface is dominantly convex in profile and erosional in origin. |
| Backslope | The steepest inclined surface of the hill slope. Backslopes in profile are commonly steep and linear, or steep and convex-concave. Backslopes are erosional forms produced mainly by mass wasting (direct gravitational action) and running water action. |
| Footslope | The inner, gently inclined surface at the base of a hill slope. The surface is dominantly concave in profile. It is a transition zone between the backslope and toeslope where colluvium and alluvium accumulate. |
| Toeslope | The outermost, gently inclined surface at the base of a hill slope. Toeslopes are constructional surfaces forming the outermost point of a hill slope where alluvium tends to accumulate. |
| Stream terrace | A natural level strip of land in a stream valley, parallel to the stream channel, originally formed near the level of the stream, and representing the dissected remnants of an abandoned flood plain or stream bed. |
| Flood plain | The nearly level fluvial (river) plain bordering a stream and subjected to periodic inundation and sediment accumulation under flood stage conditions. It is a constructional landform built of sediment deposited during overflow and lateral migration of the stream. |

### Parent Material

When rocks are exposed to atmospheric conditions, they begin to adjust to their new environment. This adjustment (known as weathering) involves processes which cause physical disintegration and chemical decomposition of the rocks. The weathering of bedrock produces unconsolidated debris serving as the parent material for soils. The parent materials undergo continued alteration and evolve into a soil reflecting the integrated effects of climate, biotic factors (plants, animals, and microorganisms), topography, and time.

Some common parent materials of the Laramie area are alluvium, colluvium, and residuum.

| | |
|---|---|
| Alluvium | Unconsolidated material transported and deposited by flowing water. |
| Colluvium | Unconsolidated material deposited on and at the base of steep slopes by direct gravitational action. |
| Residuum | Unconsolidated weathered mineral matter accumulating by disintegration and decomposition of bedrock in place. |

# 9.4: Time

Once the solid rock materials were weathered or the alluvial and colluvial materials and aeolian dunes were deposited, plants began to grow. Nitrogen was added to soil from rainfall and the nitrogen-fixing activity of lichens, algae and legumes. Soil organic matter began to accumulate, and the soils developed a distinct dark-colored A horizon. Rain water began to dissolve and leach the calcium and magnesium carbonates. Some soils were so high in lime the leaching has not depleted the supply and these soils remain calcareous. Generally, the lime inhibits further soil profile development by reducing downward leaching of clay particles.

On the soils formed from dunes and non-calcareous sandstone and shale materials, the leaching process has removed some of the exchangeable basic cations ($Ca^{2+}$, $Mg^{2+}$, $K^{+}$, $Na^{+}$) resulting in a slightly acidic soil (pH 6 to 7). On the more permeable materials, the rain water has had sufficient time to translocate silicate clay minerals from the A into the B horizon. The clay accumulation filled the pore spaces and decreased the water permeability of the B horizon. This zone of illuvial clay accumulation is defined as an **argillic** horizon.

In poorly drained soils, little leaching occurs. These soils have suffered from a lack of oxygen resulting in reduction of iron. When this process has occurred periodically, the soil exhibits mottles, while flooded soils exhibit olive and gray colors indicative of gleying.

Because extensive erosional processes have occurred, the youngest soils may overlie the oldest geologic formations (Table 1). Young soils have developed on the stabilized sand dunes, on the flood plains, and on the steep mountain uplands. Some of the oldest soils have developed on alluvial terraces and alluvial fans of the Paso Robles Formation in California.

Table 1. Soil profile development as a function of time (chronosequence).

| | Parent Material | Young Soil | Mature Soil | Old Soil |
|---|---|---|---|---|
| Horizon development | None | Slight | Well developed | Extensive |
| Typical profile | C<br>R | A<br>C<br>R | O<br>A<br>Bt<br>C<br>R | O<br>A<br>E<br>Bs<br>C<br>R |
| Time (yrs.) | 0 | 10 to 1,000 | 1,000 to 10,000 | 10,000 to 100,000 |
| Transformations | None | Humus accumulates<br>Carbonates leach<br>Eluviation dominates | Maximum humus<br>Carbonates leached<br>Clays leach<br>Eluviation<br>Maximum illuviation<br>Acidic surface | Humus decreases<br>Carbonates gone<br>Clays leached<br>Maximum eluviation<br>Extensive illuviation<br>Very acidic |
| Crop productivity | Low to moderate | Good | Maximum | Low |

# 9.5: Soil Classification

Soils in the United States are classified according to the USDA Soil Taxonomy. Soil Taxonomy includes the system of soil classification published by the Soil Survey staff of the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS), formerly the Soil Conservation Service (SCS). This system provides a comprehensive natural classification of soils based upon measurable and observable soil morphological properties. The current Soil Taxonomy is the result of many years of observations on many different soils. Probably the greatest utility of the taxonomy is for soil management and land use planning. The nomenclature used is designed to fit into any modern language. Terms were coined mainly from Greek and Latin roots, and are used as mnemonic devices for remembering the names. Many soil properties can be described by the use of the formative elements. This system of classification is hierarchical with 12 Orders subdivided into 47 Suborders, 225 Great Groups, 970 Subgroups, more than 5,000 Families and more than 15,000 Series.

The Orders (the highest level of the classification) are distinguished on the basis of properties associated with soil-forming processes on the grand scale. One soil Order is based on the absence of any distinctive characteristics. The soils in these other 11 Orders have some diagnostic features known as diagnostic surface horizons and diagnostic subsurface horizons.

The diagnostic surface horizons are called **epipedons**, from the Greek words epi (over), and pedon (soil). The epipedon includes the upper part of the soil darkened by organic matter, the upper eluvial horizons, or both. Six epipedons are recognized, but only two (Mollic and Ochric) are common near Laramie, WY.

| | |
|---|---|
| **Mollic** | A horizon—thick ( >7 inches thick ), dark (Munsell value darker than 3, moist chroma) surface horizon with a high percent ( > 50 %) basic cation saturation, high in calcium, good structure, and not both hard and massive when dry. The horizon contains at least 1 % organic matter. |
| **Ochric** | A horizon too light, too low in organic matter, or too thin to be mollic; or both hard and massive when dry. |

The diagnostic subsurface horizons are called endopedons and characterize different soils in the system. Several subsurface horizons are described in the U. S. Soil Taxonomy. Two of these (Argillic and Cambic) are common in the Snowy Range Mountains area. Not all soils have a diagnostic subsurface horizon.

| | |
|---|---|
| **Argillic** | This is a Bt horizon of illuviation (accumulation) of clay. If the soil is not eroded, this horizon is in the position of the B horizon and it has more clay than the overlying A or E horizon. The Argillic horizon is generally equivalent to the Bt horizon. Field clues for identifying argillic horizons include the following factors:<br>Higher in clay than the horizon above and generally higher than horizon below; horizon has soil structure, often being blocky or prismatic, clay films visible to the naked eye or with hand lens. Clay films are smooth, shiny clay coatings on the surface of the soil peds or aggregates. |
| **Cambic** | This is an altered or changed horizon in the position of a B horizon (an A horizon above and a C horizon below). This horizon has been changed by internal physical movement or by chemical reactions to such an extent it no longer retains the original nature of the rocks or sediments in the C horizon. Some chemical changes have occurred, but some easily weathered minerals are usually still present.<br>Usually, some leaching has occurred in the Cambic horizon and color changes have resulted, but no evidence exists of any clay movement or illuviation (i.e. clay films). The cambic horizon is generally equivalent to a Bw horizon. |

## 9.6: Soil Orders

Twelve orders exist in Soil Taxonomy, but three orders (Entisols, Inceptisols, and Aridisols) are common in the Laramie area.

| | |
|---|---|
| **Entisols** | Young or very weakly developed soils with no diagnostic horizons. They may be formed in fresh alluvium of floodplains, in fresh sand dune deposits, or on steep, eroded hill slopes where diagnostic horizons either cannot form or have not had time to form. |
| **Inceptisols** | Relatively young soils with weakly developed horizons and little accumulation of clays and organic matter. They have an ochric or umbric horizon and cambic subsurface horizon. |
| **Aridisols** | Soils with an aridic soil moisture regime and some B horizon development or a salic horizon and very little organic matter. |

# 9.7: Slope and Runoff

The steepness of slope is determined in percent (%) calculated as [(rise/run) x 100] using an **Abney level** or **clinometer**. The Abney level or clinometer is held at eye level and parallel to the slope. The level is adjusted allowing the % slope to be read directly. The absolute percent slope is the same whether sighting up slope or down slope.

The amount of soil erosion is directly related to the amount of **surface water runoff**, which depends on the water infiltration rate and the % slope. The steeper the slope and the less rapid the water infiltration rate, the more rapid the water runoff rate for a given soil. Soils having granular structure and high porosity have slower water runoff rates than do soils with massive structure and low porosity. This occurs because more water infiltrates into granular soils with less total water being available for over the surface water runoff when compared to massive soils. Other factors including vegetative cover, the type of vegetation, and the soil moisture content influence the surface water runoff rate. The greater the extent of plant vegetation covering the soil, the less soil erosion because the plant tissue intercepts the falling rain drops and greatly dissipates the energy of the falling water mass from directly hitting the soil. If a soil is moister, it requires less rainfall to reach the point where the soil becomes saturated (all pores filled) and water runoff occurs. Generally, as surface water runoff increases, soil erosion increases. The following table can be used to estimate the surface runoff rate using soil texture and the percentage of slope.

Table 2. Slopes, texture of surface horizons, and surface water runoff rates.

| Slope (%) | Textural class | Water runoff rate |
|---|---|---|
| 0-1 | All textural classes | Very slow |
| 1-2 | Sands and loamy sands | Very slow |
| 1-2 | All textures except sands and loamy sands | Slow |
| 2-6 | Sands and loamy sands | Slow |
| 2-6 | All textures except sands and loamy sands | Medium |
| 6-12 | Sands and loamy sands | Medium |
| 6-12 | Sandy loams, sandy clay loams, loams, clay loams, silt loams, silty clay loams | Rapid |
| 6-12 | Silty clay, clay, sandy clay | Very rapid |
| 12-18 | Sands and loamy sands | Rapid |
| 12-18 | All textures except sands and loamy sands | Very rapid |
| >18 | All textures | Very rapid |

# 9.8: Soil Permeability

Soil permeability is the quality of a soil enabling it to transmit air or water through the soil pores. Texture, structure, cracking, and the amount of organic matter influence the permeability. The permeability of the least permeable horizon should be estimated because this becomes the most limiting horizon for water and air movement and root penetration. The soil permeability classes are slow, moderate, and rapid.

| | |
|---|---|
| Slow permeability | < 0.6 inches of water move through the soil per hour. Slow permeability includes textures of silty clay, clay and sandy clay and soils with massive subsoils. |
| Moderate permeability | 0.6–6.0 inches of water move through the soil per hour. Moderate permeability includes textures of silt loam, loam, sandy clay loam, silty clay loam and sandy loam. |
| Rapid permeability | 6–20 inches of water move through the soil per hour. Rapid permeability includes textures of loamy sand and sand and soils with greater than 15 % gravel. |

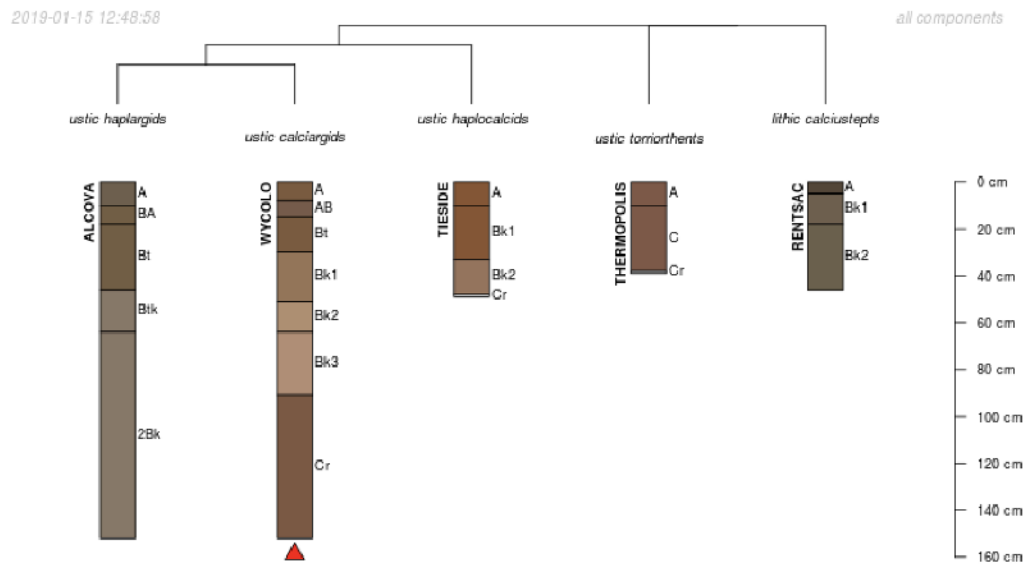
# 9.9: Laramie's Local Soils

An example of one of the most common local soils is the Wycolo series (Source: Albany County (Albany County Area), Wyoming; 1991. Soil Survey Report).

## Wycolo Series

The Wycolo series consists of moderately deep, well drained soils that formed in materials derived from interbedded limestone, redbed sandstone, and shale. Wycolo soils are on uplands, structural benches, and strath terraces. Slopes range from 2 to 20 percent. The soils formed in materials weathered from interbedded limestone, redbed sandstone, and shales. Elevations are 6,000 to 7,800 feet. The mean annual precipitation is 10 to 14 inches of which at least half occurs in the spring months. The mean annual temperature is 40 to 45 degrees F., and the frost-free season is 85 to 110 days.

Well drained; runoff is medium; moderate permeability. These soils are used mainly as rangeland. Native vegetation is western wheatgrass, needle and thread, and big sagebrush.




*Read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

# 9.10: Activity 1 - Soil Formation

1. Identify the parent material/s for each local soil. Use the appropriate name (e.g. residuum, colluvium, etc. and the rock type if the parent material is residuum; e.g. residuum – shale).

   https://soilseries.sc.egov.usda.gov/osdname.aspx

| Soil Series | Parent Material | Rock type | Soil Series | Parent Material | Rock type |
|---|---|---|---|---|---|
| **Alcova** | | | **Canwall** | | |
| **Tieside** | | | **Redrob** | | |
| **Pilotpeak** | | | **Poposhia** | | |

1. Define argillic horizon.
2. Define Aridisol.
3. Define mollic epipedon.
4. Define cambic horizon.
5. Compare the rate of nitrate fertilizer leaching in an arid climate versus a humid climate.
6. Compare the rate of soil profile development in the Brazilian rainforest versus on the prairie east of Laramie.
7. How would soil temperature, evaporation, and soil formation differ for soils forming on north versus south facing slopes (assume the same parent materials and landscape positions)?
   - North aspect:
   - South aspect:
8. What differences can be expected in two soils formed from the same parent material, but where one soil occurs on a 1 % slope (summit) and the other soil occurs on a 35 % (backslope) slope with all other soil-forming factors being the same?
   - 1 % slope:
   - 35 % slope:
9. How does soil color change with depth for the soil profile? Explain.
10. How does soil texture change with depth for the soil profile? Explain.

| | |
|---|---|
| Soil order | |
| Soil series | |
| Land use | |
| landscape position | |
| Slope % | |
| Water runoff class | |
| Water permeability class | |

**Name:** ______________________________ **Date:** ______________

**Site Name:** ______________________________ **Group name:** ____________

| | Horizon | Depth | Moist Color | | | Texture | | | Structure | Redox Features | | Carbonates |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cm | Hue | Value | Chroma | rock frag. | RF mod. | Class | | Conc. | Deplet. | Efferv. |
| | | | | | | % | | | | Y/N | Y/N | Y/N |
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |

| | |
|---|---|
| **Cl**imate | SMR: STR: |
| **O**rganisms | |
| **R**elief | |
| **P**arent **M**aterial | |
| **T**ime | |
| other comments | |

## REMINDERS/Assignments for next week's lab:

1. Study for pre-lab Quiz on material from Lab #10: Soil Ecology
2. Watch one of the videos listed under Lab 10 "Additional Resources"
   - Write a paragraph describing:
     1. One thing you learned from the video you chose
     2. An interesting fact about what you learned iii. How it relates to another field of study

# CHAPTER OVERVIEW

## 10: Soil Ecology

**Learning Objectives**

- Measure microbial transformations of carbon and nitrogen.
- Create and observe Winogradsky columns.
- Know the products of organic matter decomposition.
- Understand how the carbon to nitrogen ratio (C/N) of organic materials applied to soil influences the nitrogen availability for crops.
- Learn the carbon and nitrogen cycles.
- Explore soil organisms

**GOAL**: To understand the role of soil microorganisms in cycling of organic matter and nutrients.



**Additional resources:**

- Soil Ecology – what lies beneath https://www.nature.com/news/2008/081...l/455724a.html
- The Carbon Cycle – What goes around comes around https://www.visionlearning.com/en/li...arbon-Cycle/95
- Carbon cycle video by World Meteorological Organization: https://www.youtube.com/watch?v=E8Y6L5TI_94 (video length: 1:46)

# 10.1: Microbial Activity and the Carbon Cycle

The solid portion of soil is composed of minerals and organic matter. The organic matter includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil biota. Each of these contains many types of compounds including proteins, sugars, polysaccharides such as cellulose, hemicellulose, and starch, and complex fats, waxes, and lignins. All the lifeessential elements are contained in the collection of organic compounds found in soils.

The total amount of organic matter in soil and the nutrients it contains vary with the climate, nature of the parent material, soil pH, and the kind and amount of vegetation produced on or applied to the soil.

The process of soil organic matter decomposition and humus formation may be represented as a partial oxidation process as follows:

organic substances + $O_2$ + microorganisms + suitable environment ------> $CO_2$ + $H_2O$ + Energy (both as heat and for microbial growth) + humus + new microbial cells + inorganic plant nutrients ($Ca^{2+}$, $Cl^-$, $Co^{2+}$, $Cu^{2+}$, $Fe^{2+}$, $H_3BO_3$, $H_2PO_4^-$, $K^+$, $Mg^{2+}$, $Mn^{2+}$, $MoO_4^{2-}$, $NH_4^+$, $Ni^{2+}$, $S^{2-}$, and $Zn^{2+}$)

Under natural soil conditions, organic residues undergo an initial rapid decomposition, which liberates large amounts of carbon dioxide, water, energy, and releases small quantities of inorganic nitrogen, phosphorus, sulfur and other plant nutrients. Probably the most important function soil microorganisms serve is to recycle organic carbon to carbon dioxide, thereby maintaining photosynthesis on the earth.

The microbial oxidation process slowly decomposes plant and animal residues. Nutrients contained in the plant and animal tissue are transformed from unavailable organic forms to plant-available inorganic forms during the microbial oxidation. Hence, organic matter acts similar to a very slow-release fertilizer and buffers the soil-plant environment against drastic fluctuations in available plant nutrients. The complete cycling of carbon through plants, animals, organic residue, humus, and $CO_2$ eventually occurs.

A soil containing one percent organic matter contains up to 45 million kilocalories of potential energy per acre-furrow-slice. This energy is equivalent in heating value to about 6 tons of coal, or 31 barrels of crude oil or 168,000 cubic feet of natural gas. Soil microorganisms use only a small amount of the energy from the decomposition of organic residues for building new cells. The production of a single pound of soil organic matter from plant residues that have been amended with fertilizer nitrogen requires the total destruction of perhaps 10 to 20 pounds of plant residues to provide the energy for the process. Furthermore, whenever fresh residues are applied to soil, the decomposition of "humified" organic materials already present in the soil is accelerated.

The principal reasons for adding organic residues to soils are to modify the tilth of the soil, making seed bed preparation easier, to add plant nutrients, and to dispose of unusable or unwanted organic waste. Other benefits of adding organic matter to soils include improved soil structure, increased cation exchange capacity, increased water holding capacity, increased aeration, and a reduction in soil erosion.

# 10.2: Humus

Humus is the stable, amorphous, heterogeneous fraction of the soil organic matter remaining after the major portion of added plant and animal residues have decomposed. It is dark brown to black. It is bound to the surfaces of clays and hydrous oxides, which renders it resistant to microbial attack. The original source of the organic materials is not easily determined.

Humus has a low bulk density (0.05 to 0.25 grams per cubic centimeter), is very finely divided (colloidal), and has a high porosity and water holding capacity. It has a very high cation exchange capacity (greater than 200 milliequivalents per 100 grams of pure humus or 200 centimoles(+) per kilogram of pure humus) which allows it to retain cations such as $Ca^{2+}$, $H^+$, $K^+$, $Mg^{2+}$, $Na^+$, and $NH_4^+$ ions). Humus has a variable composition but approximates 50% carbon, 35% oxygen, 8 % hydrogen, 5% nitrogen, and 2% sulfur plus traces of all other essential elements for microbial life.

The humus content of arable soils averages between 2-3% and has a range of <1 to over 12%. Humus significantly influences physical and chemical properties of soils. It commonly is responsible for 20 to 30 % or more of the cation exchange capacity of soils. It buffers the soil against drastic chemical changes in pH in the root environment. Humus provides stability to soil peds by acting as a binding agent promoting soil aggregation.

Two factors restrict the ability to increase the humus content of a soil. First, the amount of organic material that must be applied and incorporated into the soil will be very large. The amount of organic material necessary to maintain the normal humus level in soil ranges from 1000 to 5000 kg/ha per year (1000 to 5000 pounds per acre-furrow-slice per year). Second, the addition of organic material to the soil will not permanently increase the soil's humus content. The natural physical and biological changes in the soil will hasten the decomposition of the organic residues resulting after a few years in only a small quantity of the added material remaining as humus. Cultivated soils lose humus by biological decomposition at a rate of 1 to 2% per year. Crop rotations including grasses and legumes in conjunction with conservation tillage and crop residue management can be used to sustain the humus level and productivity of agricultural soils.

# 10.3: Soil Microorganisms

Soil organisms usually comprise much less than 0.5 % of the dry soil mass. Practically nothing can be done to permanently alter the microbial population of a soil. Normally, the soil contains a vast array and abundance of organisms. Consequently, most direct additions of organisms (**inoculation**) to this community will be ineffective. Usually, microbial populations will be altered more by changing the crop growing in the soil than by adding other microorganisms. However, in soils that have been steam sterilized or fumigated to control plant pathogens, the microbial numbers have been reduced greatly (but not eliminated). Adding fresh soil to a steam-sterilized soil will reintroduce many microbes but may add undesirable plant pathogenic microbes with the fresh soil. The average biomass distribution in an acre-furrow-slice of soil is approximately as presented in Table 1.

Table 1. Distribution of living organisms and organic matter in an acre-furrow-slice (about 2,000,000 lbs. soil) of a highly productive soil.

| **Soil Organisms** | **Estimated biomass** | Number of organisms | |
|---|---|---|---|
| | lbs./AFS or kg/ha† | Number/AFS | Number/g |
| Earthworms | 200 to 500 | $1.5 \times 10^{5}$ | $1.6 \times 10^{-4}$ |
| Myriapods | 5 to 40 | $2.2 \times 10^{6}$ | $2.4 \times 10^{-3}$ |
| Insects | 100 to 200 | $5.05 \times 10^{3}$ | $2.3 \times 10^{-6}$ |
| Rodents | 50 to 100 | $1.3 \times 10^{2}$ | $1.4 \times 10^{-7}$ |
| Nematodes | 1 to 2 | $9.1 \times 10^{7}$ | $1.0 \times 10^{-1}$ |
| Plant roots + root hairs | 2,500 to 4,000 | $1.13 \times 10^{13}$ | $1.35 \times 10^{4}$ |
| Bacteria | 3,000 to 4,500 | $2.4 \times 10^{18}$ | $2.6 \times 10^{9}$ |
| Actinomycetes | 1,000 to 2,000 | $1.3 \times 10^{17}$ | $1.4 \times 10^{8}$ |
| Fungi | 2,500 to 4,500 | $3.3 \times 10^{15}$ | $3.7 \times 10^{6}$ |
| Protozoa | 10 to 75 | $1.2 \times 10^{13}$ | $1.3 \times 10^{4}$ |
| Algae | 5 to 10 | $2.5 \times 10^{14}$ | $2.8 \times 10^{5}$ |
| Dead organisms + humus | 40,000 to 60,000 | --- | --- |

*Source: Brady, N.C. and R.R. Weil. 2002. The nature and properties of soils. 13th ed. Prentice Hall, Upper Saddle River, NJ.* †AFS = acre-furrow-slice = 2,000,000 lbs. of dry soil which is assumed to contain about 2.5 % humus. 1 hectare-15 cm = 2,000,000 kg of dry soil which is assumed to contain about 2.5 % humus.

A number of conditions affect microbial populations in soils. The optimum temperature range for decay organisms is between 70-100 °F (about 20-40 °C). Soil temperatures outside this range will retard the activity of most soil organisms. Excessive water in soil reduces the numbers and kinds of living organisms due to poor aeration. However, at low moisture levels soil organisms thrive better than do higher plants. Numbers of fungi, bacteria and actinomycetes vary with soil pH. If pH of the soil is <6.0, the fungi become the dominant soil microorganisms. The supply of nutrients, organic material for energy, and free oxygen gas affect microbial numbers. Fortunately, optimum soil conditions for most plants and for most soil microorganisms are similar.

# 10.4: Mineralization

Mineralization is the process of converting elements from an organic form to an inorganic form by microbial decomposition. After the addition of organic materials to soil, the rate of release of carbon dioxide reaches a peak in a few days and then tapers off with time. The peak is associated with an explosive growth in the microbial population, which consumes plant nutrient ions that are needed for building new cells. The decline in carbon dioxide production occurs because the microbes have consumed most of the readily decomposable high energy organic materials. The rate of carbon dioxide production and microbial population is dramatically reduced simultaneously.

As the microbial activity declines, the dead cells are destroyed, releasing nutrients in plant available inorganic form. Nitrogen is released as ammonium ($NH_4^+$). Sulfur is released in a reduced form as sulfide ($S^{2+}$). Most other nutrients are released in the ionic form (e.g. $H_2PO_4^-$). The mineralization of large quantities of nitrate and sulfate signal the completion of the major microbial degradation process

# 10.5: Carbon/Nitrogen Ratio

The proportion of carbon to nitrogen in the organic matter is an important factor in controlling microbial activity. Organic material having a high carbon to nitrogen ratio (C/N), such as wheat straw at about 80/1, will decay relatively slowly because the material contains insufficient nitrogen to satisfy the growth requirements of the decay producing microorganisms. Soil microorganisms often retain the available nitrogen for prolonged periods. This nitrogen immobilization by microbes can create nitrogen deficiencies in the soil and lead to reduced plant growth. Legume residues, such as clovers and alfalfa, have low C/N ratios (< 30/1) and decay very rapidly in the soil. They release large amounts of $CO_2$ and some nutrients for plant growth. Materials from young plants, having low C/N ratios, decompose more rapidly than do materials from old plants, having higher C/N ratios. A list of common organic materials and their C/N ratios is provided in Table 2.

Table 2. The C/N ratio for some common organic materials.

| Organic substance | Carbon | Nitrogen | C/N ratio |
|---|---|---|---|
| Microorganisms | 50 | 6.2 | 8/1 |
| Humus | 50 | 4.5 | 11/1 |
| Alfalfa | 43 | 2.5 | 18/1 |
| Clover hay | 40 | 2.0 | 20/1 |
| Barnyard manures | 35 | 1.4 | 25/1 |
| Sewage sludge | 48 | 1.7 | 28/1 |
| Rye grass | 40 | 1.3 | 30/1 |
| Peat moss | 48 | 0.8 | 60/1 |
| Corn stalks | 44 | 0.6 | 73/1 |
| Barley straw | 45 | 0.1 | 450/1 |
| Fir bark | 54 | 0.1 | 540/1 |
| Redwood sawdust | 51 | 0.05 | 1020/1 |

Microbial decay of organic matter releases copious amounts of carbon dioxide. In this way carbon is cycled from the soil to the air, completing the carbon cycle that began with photosynthesis. More microbial activity is synonymous with a greater production of carbon dioxide by soil microbes.

Composting of organic material is one way to manage the overall decay process. This allows time for the microbes to decompose most of the organic residues.

# 10.6: Nitrogen Cycle

The nitrogen in humus and other organic materials released by microbes during the decay process can undergo several transformations in the soil. The ammonium ($NH_4^+$) is oxidized by *Nitrosomonas* to nitrite ($NO_2^-$) and is further oxidized by *Nitrobacter* to nitrate ($NO_3^-$). These two ions can be immobilized by plants and soil microorganisms or be changed in the nitrogen cycle.

# 10.7: Major components of the Nitrogen Cycle

| | |
|---|---|
| Nitrogen Fixation | Nitrogen fixation is the microbial conversion of nitrogen gas ($N_2$) to ammonium ($NH_4^+$). Various bacteria in plant roots perform this process. Recently, soil microbiologists have reclassified all of the microorganisms that fix nitrogen. The following list provides the new classification of these microbes and the plants that they infect. |
| Mineralization | Mineralization is the conversion of organic nitrogen to inorganic ammonium ($NH_4^+$). |
| Nitrification | Nitrification is the oxidation of ammonium ions ($NH_4^+$) to nitrate ions ($NO_3^-$). |
| Immobilization | Immobilization is the assimilation of ammonium ($NH_4^+$) and nitrate ($NO_3^-$) into tissue |
| Denitrification | Denitrification is the reduction of nitrate ($NO_3^-$) to nitrogen gases ($N_2$, $N_2O$, NO, and/or $NO_2$) under anaerobic soil conditions (in very wet soil). |
| Volatilization | Volatilization is the chemical conversion of ammonium ($NH_4^+$) ions to ammonia gas ($NH_3$) in high pH soils and is accelerated by drying of the soil. |

*Read through and complete the following activity and questions. All questions should be answered and completed labs are due at the end of the laboratory period. No late work will be accepted.*

# 10.8: Activity 1 - Soil Incubation

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

## Microbial Observations

1. Carefully retrieve the 3 plastic bottles from the incubation shelf keeping them vertical during the transfer from the incubation area to your desktop
2. Open each bottle one at a time. Examine the contents of the bottles by performing the procedures indicated below.
   1. Move your hand across the top of the bottle bringing the air towards your nose.
   2. Smell the air and record the odor of what you smell.
   3. Examine the soil surface of each bottle for fungi using first your eyes and then the microscope. Fungi produce fungal mycelia as tissue that has the appearance of fine cotton threads or spider webs.
3. Rate the appearance of fungal mycelium in the **control, alfalfa, and sawdust** bottles using the terms none, slight, abundant, or overgrown.

| | Odor detected | Appearance of fungal mycelium |
|---|---|---|
| Control | | |
| Alfalfa | | |
| Sawdust | | |

## Carbon Dioxide

During the microbial incubation, the microbes decomposed the organic amendments and the humus in the soil, releasing carbon dioxide into the atmosphere of the incubation bottle.

Date experiment was initiated = ____________ Date analyzed = __________________

Number of days of incubation = _____________

# 10.9: Activity 2 - Carbon Dioxide

Name: ______________________________

Section: ______________________________

Student ID#:___________________________

1. Draw a simple version of the carbon cycle. (Refer to your textbook for help.) Include the atmosphere and plants.
2. What process of the carbon cycle is responsible for releasing $CO_2$ into the soil atmosphere?
3. How might this release of $CO_2$ into the soil atmosphere affect the soil pH? Write a chemical reaction for this process.
4. Rank the soils in order of probable amount of $CO_2$ released, from the greatest amount released to the least amount released (begin with the soil with largest quantity of $CO_2$ released. Briefly explain your answer.

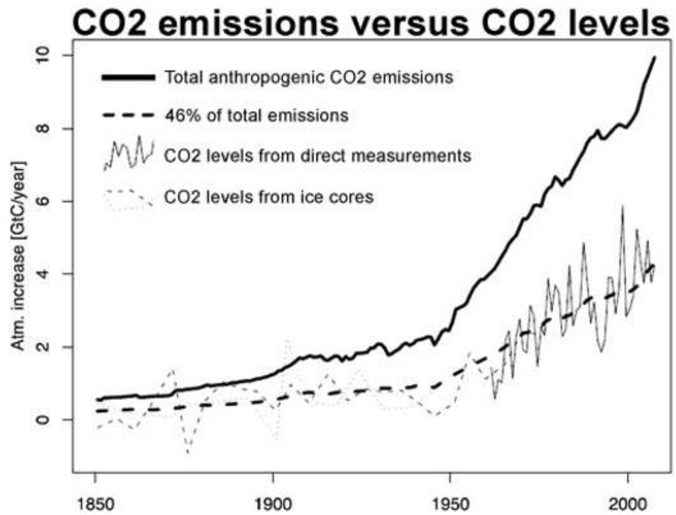



Figure 1: *Observed increase atmospheric $CO_2$ derived from direct measurements, taking the average of Mauna Loa (Hawaii) and the South Pole (thin solid line) and two ice cores: Law Dome (dashed thin line) and Siple (thin dotted line). This is compared to total anthropogenic emissions (thick solid line) and 46% of total emissions (thick dashed line). (Knorr 2009)*

5. Increasing temperatures on earth is attributed to an increase in carbon dioxide, which traps heat via the greenhouse effect. The increased atmospheric carbon dioxide is due to the burning of fossil fuels. Explain why carbon dioxide levels in the world's atmosphere has lagged behind emissions. Consider possible carbon sinks that may be keeping carbon in terrestrial and marine environments.

# 10.10: Activity 3 - Soil Nitrate-Nitrogen Analysis

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

Adapted from: T.K. Hartz. 2010. Using the Pre-Sidedressing Soil Nitrate 'Quick Test' to Guide N Fertilizer Management. UC Vegetable Research and Information Center.

Safety Considerations: Read hazard information below on today's experiment. Wear appropriate eye protection. Avoid contact with skin for all corrosive and irritating reagents. If contacted, flush with copious amounts of water and inform your instructor immediately.

Hazard information: Calcium chloride (0.01 M $CaCl_2$) may cause eye, skin, and respiratory tract irritation.

## Procedure

1. After viewing each of the three treatment containers with the binocular microscope, carefully add 50 ml of the 0.01 *Molar* calcium chloride extracting solution to each of the containers.
2. Using a glass stirring rod, stir mixture for 30 seconds. Rinse stirring rod and return to proper location.
3. Allow containers to sit undisturbed for 15 minutes while soil particles settle.
4. After the settling period, obtain one nitrate strip for each container and carefully tilt the container to about a 45-degree angle to allow enough depth of solution for dipping of the test strip. Dip the test strip with tab facing down to avoid floating organic matter. Lightly shake off any excess solution and read the nitrate color from the test strip against the color chart at one minute after dipping. The color pad at the end of the test strip is the one to read for nitratenitrogen.
5. **Cleanup**: Place the nitrate test strip into a trash can and thoroughly rinse the plastic container with tap water to remove all soil and extraction solution, dumping rinse material into bucket in sink. Place plastic container in proper storage container.

## Nitrate Observations

| | Color of the test strip | Amount of nitrate produced (ppm) |
|---|---|---|
| Control | | |
| Alfalfa | | |
| Sawdust | | |

## Nitrate Questions

1. Rank the treatments (control, alfalfa, sawdust) in terms of the amount of nitrate produced in each treatment, from greatest to least amount of nitrate produced.

Immobilization of nitrogen occurs when the carbon to nitrogen ratio (C:N) is high (≥30:1) and an insufficient level of ammonium and nitrate exist in the soil to meet the needs of the microorganisms that are decomposing the organic matter. Usually, immobilization occurs when the nitrate level is nearly zero. Immobilization occurs during the initial part of the degradation of most organic materials in the soil. After a sufficient period of time, the microbes will run out of energy after they have decomposed most of the organic material and release large amounts of carbon dioxide. Once the microbes have run low on energy, they begin to release extra ammonium into the soil by the process of mineralization. The ammonium produced in the soil is rapidly converted to nitrate by the nitrifying bacteria. Consequently, after mineralization, the nitrate level in the soil amended with an organic material will be higher than was the nitrate level of the original soil.

2. Based on the discussion above, briefly explain the ranking (#1) (the amount of nitrate produced in each treatment).

3. Do your results for the amount of nitrate in each treatment make sense in terms of the C/N ratios of the various treatments?

4. What would be the effect on plants if a finely ground organic matter having high C/N (85/1 straw) were added to the soil?

5. What 3 practical steps can be taken to reduce nitrogen immobilization by microorganisms and the resulting nitrogen deficiency in the plants when applying high C/N organic materials to soils for the next crop?

---

# 10.11: Activity 4 - Decomposition Questions

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

1. Will various soils high in organic matter and humus always have a high level of microbiological activity—Yes or No? (Circle choice) Explain.
2. Explain how the C/N ratio of various organic materials influences the time required for microbiological decomposition.
3. List 5 specific benefits of adding organic residues to soils.
4. What are the 6 most important factors affecting the decomposition of crop residues and other organic waste materials added to soil? (Hint—Consult your text book for possibilities.)

# 10.12: Activity 5 - Winogradsky Columns

Name: ______________________________

Section: _____________________________

Student ID#:__________________________

*Adapted from HHMI BioInteractive activity "Winogradsky Columns: Microbial Ecology in the Classroom"*

## Introduction

Microorganisms play an essential role in cycling elements that make the planet habitable for all other types of organisms. The diversity of these simple life forms is evident in the myriad of ecological niches they inhabit, from hydrothermal vents to the acidic lining of your stomach.

In this activity, you will observe a sampling of the diverse microorganisms that live in your local environment. Winogradsky columns will be set up-simple devices for constructing a stratified ecosystem-that illustrate different types of microbial metabolism in a colorful way.

Samples will be set up at the beginning of the semester and you will be required to make observations four times throughout the the spring. Answers to the questions below are due in **Lab 10: Soil Ecology** so ensure that you have completed these by that lab period.

## Materials

- 4 clear containers
- 1-4 disposable containers (plastic baggies) for mixing soil
- 1 trowel for digging sediment sample
- 4 small labels
- Water
- 1 bucket container large enough to hold 6-10 cups of soil
- Large measuring cup for measuring soil and mixture
- A carbon source (organic forest litter); appx 1 cup loosely packed
- 6-10 cups soil
- Sulfur source; raw egg yolk is best
- Large mixing spoon
- 1 funnel

## Procedure

Four Winogradsky columns will be set up: a control column and columns that contain added carbon, added sulfur, and carbon and sulfur. Make sure to set aside a few minutes on each of the assigned observation weeks during the experimental period to make observations and take photos of your columns.

Collect the Soil Sample

1. Identify a soil source in your area-anywhere with soil and water is appropriate, such as a stream, creek, lake beach (sand) or even back yard.
2. Take 2-3 photographs of your sample site to illustrate the location where your sediment was collected.
3. Collect approximately 10 cups of sediment in the bucket. The sample should be wet. Avoid or pick out rocks, sticks and leaves; include some additional water from the sample site if possible.

Assemble the Winogradsky Columns

1. Label 4 containers: "Control," "Carbon," "Sulfur," and "Carbon and Sulfur."
2. Label 4 disposable containers corresponding to the plastic containers and add appx 1.5 cups soil to each. Do not cross-contaminate samples.
3. For "Control" column, skip to step 5
4. For the other three containers,
    1. For "Carbon" column: Add ½ cup shredded newspaper (loosely packed) to soil and mix with spoon or trowel
        - The newspaper contains cellulose, a source of carbon
    2. For the "Sulfur" column: Add the yolk of a raw egg to the soil and mix. If using hardboiled eggs, crumble the yolks.
        - Egg yolk is a source of calcium sulfate in the column
    3. For the "Carbon and Sulfur" column: Add both nutrients as described in steps a and b.
5. Mix each of the samples thoroughly. Make sure to remove any large debris such as leaves, rocks or sticks. Slowly mix in water until the mixture has a milkshake consistency.
6. Using a large spoon, slowly add appx 1 cup of the mixture to the appropriately labeled plastic column. As you add the sample, tap the column on the counter to release any trapped air in the column.
7. Add water on top of the soil until there is a 2 cm layer of water on the surface, and air at the top of the column.
8. Place the lid on each column and turn a half turn. **Do not** tighten the lid!
9. Place all 4 columns in a well-lit place (window).
10. Using a camera or phone, take a photograph of the columns to document week 0 of experiment.

## Make and report observations

### A. Weekly observations

You will observe your Winogradsky columns throughout the semester during labs 3, 5, 8 and 10. Spend a few minutes on assigned dates recording your visual observations and take a photograph (remember to label photos with the week the photo was taken).

Consider the following questions when recording observations:

- Has the color of the soil changed?
- Has the color of the water changed?
- What differences between the columns do you observe?
- Does the soil appear to have shifted or settled?
- Do you see any layers forming in the sediment? In the water?
- How does the thickness of the layers change from week to week?
- Are there any differences between the side facing the light and the side away from the light? Be sure to keep the same orientation relative to the light if you must move the columns.
- Sketch the columns, in color, three times over the 8-week experiment.

| Date | Observations during the week of: | Control | Carbon | Sulfur | Carbon & Sulfur |
|---|---|---|---|---|---|
| | 0 | | | | |
| | Lab 3 | | | | |
| | Lab 5 | | | | |
| | Lab 8 | | | | |
| | Lab 10 | | | | |

## Questions

1. How do your columns differ? How are the similar?
2. Did you observe changes in the control column? If so, explain why they occurred
3. Winogradsky columns form oxygen concentration gradients. Predict the distribution of oxygen throughout the column. Consider the soil, water and air
4. Winogradsky columns form sulfide concentration gradients as well. In the columns that contain egg yolk, predict how sulfide will be distributed throughout the column.
5. Purple sulfur bacteria and green sulfur bacteria are two types of bacteria that use sulfide to support photosynthesis. In general, green sulfur bacteria tolerate higher levels of sulfide than purple sulfur bacteria do. Predict where the green and purple sulfur bacteria would be in relation to each other.
6. If samples were extracted from various layers of all the columns, where would you find photosynthetic organisms such as cyanobacteria and algae? Why?
7. Explain how Winogradsky columns illustrate the diversity of microorganisms found on Earth today in terms of the diversity of niches they occupy.

CHAPTER OVERVIEW

# 11: Makeup Lab: Land Use

**Learning Objectives**

- To conduct a photographic scavenger hunt for soil science related items/concerns/concepts.

**GOAL**: To become familiar with soil and the related uses made of these soils in the local area.



**Instructions**

- Form a group of no more than 4 students from the introductory soil science course or work alone.
- Identify, locate, and photograph at least 10 of the following items. You will receive 1 point for each item up to 10 points. If you are unsure about any of your photos – take a few extra to ensure you get the full 10 points.
- As a group, assemble a document that contains the photographs along with a detailed caption that answers the question posed in the table below. Your lab instructor may require a presentation, poster, or word document.
- Be sure that everyone's first and last names are on the finished assignment. Ask your lab instructor how to submit this assignment.

## 11.1: Information and Activity

| Item/concern/concept to be photographed | Caption requirements |
|---|---|
| A. Evidence of good or sound land management. | What is the land use and why is it considered good management? |
| B. Evidence of poor land management. | What is the land use and why is it considered poor management? |
| C. Soil structure – from a previously exposed soil profile | What type of structure is this and where was the photo taken? |
| D. Evidence of proper water management | What is it and why is this smart water usage? |
| E. Parent material – a photo from aboveground is fine | What is this PM and how do you know this? |
| F. Rock | What is this rock, where did you find it, and how do you know that it is correctly identified? |
| G. Mineral | What is this mineral and how do you know that it is correctly identified? |
| H. Soil as engineering media | Where are you and why is this soil considered engineering media? |
| I. Soil as agricultural media | Where are you and what is being grown in this soil? |
| J. Evidence of biological activity in the soil | What organism is responsible for this activity and is the activity beneficial or harmful and why? |
| K. Soil organism | What is the organism and how did you capture it? How does this organism affect the soil? |
| L. Soil order – a photo of any soil order taken from aboveground – unless there is an open soil pit or exposed soil | What is the soil order and how can you be sure that it is correctly identified? |
| M. Something used in everyday life that is reliant on the soil | What is it and why is it reliant on the soil? |

You may only photograph 2 items/concerns from each row (i.e. 2 soil orders, 2 parent materials, 2 soil structures…). You will receive an extra point (for a total of 11/10) if you take a photo of the entire group in front of one of the items!

### *Land Use Planning*

#### *Basic Concepts of Land Use Planning*

A general map of the local soils plus detailed soil maps is essential for sound land use planning. Soil survey reports usually evaluate soils for their limitations in various land use categories. Some of these common land use categories include dwellings as homes or light industry, septic tank drainage fields, highways, railroads, airport runways, campground and picnic areas, recreational activities (golf courses, parks etc.), cultivated crop production, rangeland productivity, forest products production, and watershed management.

Some of the most commonly monitored soil properties bearing upon land use decisions include slope, susceptibility to erosion, water drainage, wetness, water overflow, pending or flooding hazard, water permeability, soil depth to hard rock, shrink and swell potential, corrosion potential, and the ability of the soil to bear highways and large buildings.

#### *Land Use Planning Process*

The land use planning process requires balancing the concerns for the physical nature of the soil (texture, structure, and water holding ability), chemical characteristics (pH, electrical conductivity, exchangeable sodium percentage, and plant nutrient fertility), and biological productivity (microbial activity, C/N ratio, crop yields) with the economic considerations (current market value of the land, tax valuation, and effectiveness of agricultural marketing) considering the legal aspects (zoning and ordinances relative to land use), the political acceptability of any future decisions regarding the use of the land, the acceptability of changes in land use (based upon social and cultural mores, customs, attitudes, and beliefs) and the practicality of developing a manageable and effective plan which can be implemented and administered in a meaningful and efficient manner.

At the heart of the planning process regarding land use are philosophical and legal conflicts regarding how we view the use and ownership of land. To what extent should the rights of the individual land owner be dominated by public good obtained by using the land in some other manner? Does the private land owner (farmer or rancher) have an unrestricted right to make a profit by selling the land (often for urban development) when society may deem this land should remain in agriculture or be preserved as a green belt area? What local, county, state, or federal laws will prevent changing the current use of a particular parcel of land? Thus, serious attention to the political consequences of any land use decision must be given through local governmental bodies (County Boards of Supervisors) or other regional authorities (Bureau of Land Management).

Land use planning is a continuous process that is continually being changed and modified as the values of individuals and communities change and as the needs and requirements of people and communities change over time. Land use planning always uses hindsight to project the needs, requirements, and potentials for future generations.

#### *Agricultural uses*

Intensive crop production requires suitable highly productive soils. Cultivation should be avoided on lands not suitable for intensive agricultural production or on highly erodible land. Future generations expect a continued supply of healthful and affordable food. This will require a sustainable farming enterprise that will insure continued soil productivity for the future.

Increasingly, people are concerned about both the future productivity of the land and about the nature of the overall quality of the soil health (microorganisms and other organisms living in and on the soil). Best management practices (BMPs) must be followed to assure continued successful agricultural production with minimum consequences (limited nitrate leaching or pesticide contamination of ground waters). The value of prime farm land must be recognized and appreciated.

In the semi-arid portions of the U.S., erosion due to the wind dominates. In these areas, windbreaks and shelter belts are constructed using trees and shrubs. On the open prairies, wheat is planted in swaths perpendicular to the wind to reduce soil loss by high winds.

The presence of rare or endangered species on agricultural lands is increasingly pitting farmers and ranchers against those with a concern for the ecosystem and the environment.

#### *Forest, Range, Water, and Wildlife uses*

Wildlife require necessary food and water sources plus protective cover among trees and shrubs.

Rangelands have been abused by keeping livestock on a single parcel of land for too long a period. Modern ranchers understand the importance of rotating livestock around on various portions of the land, rather than allowing the animals to remain on the land 365 days a year.

Range land management requires planning to control undesirable plants on the range along with potential re-seeding plus rotational grazing systems to reduce compaction and soil erosion. Timber management includes siting of road locations to minimize soil erosion. Clear-cutting practices increase soil erosion; thus, proper land management decisions require sensitivity to and awareness of the need to leave the forest debris on the ground after clear-cutting to prevent excessive soil erosion. However, this timber debris is a fire hazard and may cause problems for replanting the land. Livestock grazing will need to be controlled until the trees are beyond the stage where they would be killed by animal grazing. Fertilizer applications on steep forested land may result in fertilizer movement into adjacent streams on steeply sloping landscapes.

Soil erosion into streams in mountainous areas has damaged many fish spawning areas. Natural habitat restoration is needed to ensure logging or mining activities in mountainous regions do not adversely impact stream water quality. Wildlife habitat management is increasingly seen as an important facet of wise land use planning. This must be based upon an entire ecosystem approach where soil is only one component of the entire management process.

Most forest and rangelands serve as watersheds that provide substantial amounts of surface water collected into dams and reservoirs for irrigation or for municipal water uses. The soils must be protected to ensure the water is of the highest quality. Also, eroding soil must be prevented from entering these dams and reservoirs. The eroded sediments would otherwise settle behind the dam or reservoir, reducing the total volume of water that could be held by the dam or reservoir.

#### *Recreational uses*

Steep slopes are inappropriate for campsites. Stone-free sites are most desirable for camping. Steep slopes are essential for ski runs in mountainous areas. Mountainous terrain is desirable for vistas and viewing while hiking. Hiking trails are prone to severe erosion and special attention must be paid to diverting water effectively from the trail.

#### *Urban Planners*

Urban planners need soil information to assist in planning future urban growth and areas for future expansion. This includes considerations for future open space preservation, water drainage and water recharge locations, and other specific local soil concerns. They must consider the importance of protecting agricultural land as prime farmland for future generations. Often, urban communities are sensitive to the need for aesthetic conditions such as green belts and parks. Stream beds and poorly drained areas can often be developed for green belts and avoid the damage created by constructing buildings or highways on these poorly drained areas.

Soil engineering properties are particularly of concern relative to construction sites. Storm water runoff, sewage water treatment, and promoting clean air and water are important soil functions to consider when making urban plans. The spatial relationships of the soils and the native vegetation patterns are of primary importance relative to parks, playgrounds, golf courses, poorly drained areas, green belts and other open spaces. An assessment of the local geology and natural resources plus existing highways, railroads, rivers, and other transportation routes must be included in any long-term plan.

#### *Zoning Regulations*

Almost every proposed land use will have some conflicting use as viewed by various members of the community. Consequently, all land use decisions are hotly debated political issues. These issues usually are described as zoning decisions. Libertarians want the government to have no role in any aspect of their lives. On the other side are various specific interest groups and environmental groups advocating the government must intervene to protect the soil for future generations. Poorly drained areas (flood plains) must be avoided for most human habitation. Steep hillsides which are prone to slope failures must be avoided for housing developments. Poorly drained and wet soils are not suitable for individual home septic tanks. Zoning maps are commonly developed delineating areas with severe or hazardous conditions for potential zoning.

The needs associated with an increase in population and growth must be balanced with the availability of existing and projected expansion of possible resources available to serve this increase in population. The rights of property owners and farmers to sell their land must be balanced against a higher good to the community to preserve or protect such land for future generations.

#### *Construction of Buildings, Pipelines, and Highways*

If soils are strongly acidic, the concrete foundations of buildings may corrode. Withdrawing ground water from areas with a high shrink and swell potential may cause cracking of the building foundation. Often, buildings are constructed in river flood plains where the water may only rise 1 in 20 or fewer years. Flooding can cause severe damage to such structures.

Knowledge of soil engineering properties is essential for any decisions relative to siting various structures on the soil. These properties include the depth of the major soil horizons, the liquid limit, plastic limit, plasticity index, maximum dry bulk density, optimum moisture content, mechanical analysis (texture), AASHTO and Unified classifications of soil characteristics, water percolation rate, soil bearing strength, the shrink-swell ratio, the soil pH, the depth to the water table and depth to bedrock.

Buried pipelines in soils are subjected to severe corrosion associated with high salt content of soils, strong acidity conditions or to poorly drained soil environments.

Highways require a stable base on the soil. Frequently, poorly drained areas can result in frost susceptibility of pavement and later pothole development. In some circumstances, the soil may be too soft or to unstable and may have to be removed and replaced with more appropriate fill earth material prior to construction. Some soils will settle unevenly resulting in bumps in the roadbed.

#### *Problems with Land Use Planning*

Commonly recognized problems include urban sprawl, fragmentation of rural and urban land parcels, over-development, inadequate attention to the need for open space, inflation, and increasing tax valuation of the land. These problems arise mainly because decisions are based solely on political processes or because major constituent groups and stake holders have been ignored in the planning process. Planning takes time. Often, people are in too great a hurry to complete a plan with the consequence of having considered only some (but not all) of the critical factors necessary to make a fully informed decision relative to the use of a particular parcel of land.

Frequently, the reclassification of using land from agricultural to residential has the consequence of eventually driving farmers off their land. People have a romantic ideal of rural life. However, the new homeowners complain about the smell or noise of livestock production or the potential threat from pesticide drift when the grower applies pesticides to the crops. In addition, the tax valuation of land adjacent to agricultural land is often reclassified thus making the land tax more than the profit per acre that can be obtained by the farmer or rancher continuing to operate as they have in the past.

Future land use decisions will need to include a greater consideration for the limited natural resources (soil, air, and water) along with a deeper appreciation of the environment and the ecological relationships of all organisms (including humans) within the ecosystem. Society will have to embrace a better understanding and recognition of the importance of sustainable practices rather than the extremely high energy expenditures and horrendous water waste which occurs with many current products and practices. Population restrictions or other limitations may be required as the society continues to grow in unplanned and unanticipated ways.

#### *References*

Bartelli, L. J., A. A. Klingebiel, J. V. Baird and M. R. Heddleson. 1966. Soil surveys and land use planning. Soil Science Society of America and American Society of Agronomy. Madison, WI.

Beatty, Marvin T., Gary W. Petersen, and Lester D. Swindale. 1979. Planning the uses and management of land. Agronomy 21. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Inc. Madison, WI.

# Index

# Glossary

**Sample Word 1** | Sample Definition 1

# Detailed Licensing

## Overview

**Title:** Introduction to Soil Science Laboratory Manual (Schwyter and Vaughan)

**Webpages:** 90

**All licenses found:**

- CC BY 4.0: 96.7% (87 pages)
- Undeclared: 3.3% (3 pages)

## By Page

- Introduction to Soil Science Laboratory Manual (Schwyter and Vaughan) - *CC BY 4.0*
  - Front Matter - *CC BY 4.0*
    - Title Page - *CC BY 4.0*
    - InfoPage - *CC BY 4.0*
    - Table of Contents - *Undeclared*
    - Licensing - *Undeclared*
  - 1: Introduction to Soil Science and Soil Formation - *CC BY 4.0*
    - 1.1: Introduction - *CC BY 4.0*
    - 1.2: Activity 1 - Soil Formation - *CC BY 4.0*
    - 1.3: Activity 2 - Soil Horizons - *CC BY 4.0*
    - 1.4: Activity 3 - Soil Color - *CC BY 4.0*
    - 1.5: Activity 4 - Soil Texture - *CC BY 4.0*
    - 1.6: Activity 5 - Soil Structure - *CC BY 4.0*
  - 2: Parent Materials and Mineralogy - *CC BY 4.0*
    - 2.1: Introduction - *CC BY 4.0*
    - 2.2: Activity 2 - Minerals - *CC BY 4.0*
    - 2.3: Activity 2 - Rocks - *CC BY 4.0*
    - 2.4: Activity 3 - Weathering - *CC BY 4.0*
    - 2.5: Activity 4- Rocks to Parent Material - *CC BY 4.0*
  - 3: Soil Taxonomy - *CC BY 4.0*
    - 3.1: Introduction to Soil Taxonomy - *CC BY 4.0*
    - 3.2: Pre-Class Activity- Classified Location Exercise - *CC BY 4.0*
    - 3.3: Activity 1- Horizons and Characteristics - *CC BY 4.0*
    - 3.4: Activity 2 - Taxonomic Class - *CC BY 4.0*
  - 4: Soil Survey and Mapping - *CC BY 4.0*
    - 4.1: Introduction- Soil Survey Reports - *CC BY 4.0*
    - 4.2: What is a soil survey? - *CC BY 4.0*
    - 4.3: Challenges in soil surveying - *CC BY 4.0*
    - 4.4: Responsibility for soil surveys - *CC BY 4.0*
    - 4.5: Activity 1 - Using Web Soil Survey - *CC BY 4.0*
  - 5: Soil Physical Properties & Soil-Water Relations - *CC BY 4.0*
    - 5.1: Introduction- Soil Texture, Structure and Water Relations - *CC BY 4.0*
    - 5.2: Bulk Density, Porosity, Particle Density of Soil - *CC BY 4.0*
    - 5.3: Bulk Density - *CC BY 4.0*
    - 5.4: Particle Density - *CC BY 4.0*
    - 5.5: Porosity - *CC BY 4.0*
    - 5.6: Sampling - *CC BY 4.0*
    - 5.7: Soil-Water Relations - *CC BY 4.0*
    - 5.8: Soil Erosion - *CC BY 4.0*
    - 5.9: Activity 1 - Bulk Density and Porosity of Soil Cores - *CC BY 4.0*
    - 5.10: Activity 2 - Soil Moisture - *CC BY 4.0*
    - 5.11: Activity 3 - Soil Water Movement - *CC BY 4.0*
    - 5.12: Activity 4 - Infiltration Estimates and Available Water Calculations - *CC BY 4.0*
    - 5.13: Activity 5 - Effects of Soil Erosion - *CC BY 4.0*
  - 6: Science Communication - *CC BY 4.0*
    - 6.1: Introduction - *CC BY 4.0*
    - 6.2: Activity - *CC BY 4.0*
  - 7: Soil Chemistry - *CC BY 4.0*
    - 7.1: Introduction - *CC BY 4.0*
    - 7.2: Activity 1 - Soil Colloids - *CC BY 4.0*
    - 7.3: Activity 2 - Soil Charge - *CC BY 4.0*
    - 7.4: Activity 3 - Soil Charge Calculations - *CC BY 4.0*
    - 7.5: Activity 4 - Soil pH and Electrical Conductivity - *CC BY 4.0*
    - 7.6: Activity 5 - Reduction and Oxidation Reactions - *CC BY 4.0*
  - 8: Soil Health & Quality - *CC BY 4.0*
    - 8.1: Introduction to Soil Health - *CC BY 4.0*
    - 8.2: Activity 1 - Aggregate Stability - *CC BY 4.0*
    - 8.3: Activity 2- Nutrient Cycling and Availability - *CC BY 4.0*