

TABLE OF CONTENTS

Introduction.....	1
Materials List for Soils Labs.....	2
Soils Labs	
Lab #1: Soil Morphology.....	4
Exercise A: Determination of Texture by Feel	5
Exercise B: Soil Structure Types	9
Exercise C: Soil Color	11
Study Questions	11
Lab #2: Soil Texture, Density, and Porosity.....	13
Exercise A: Particle Size Analysis.....	17
Exercise B: Measurement of Bulk Density Using a Soil Core	23
Exercise C: Measurement of Particle Density	24
Study Questions	26
Overheads to Use	28
Lab #3: Cation Exchange and Soil Acidity.....	32
Exercise A: Measurement of Soil pH	37
Exercise B: Cation Exchange in an Acidic Clay Loam Soil.....	37
Study Questions	38
Lab #4: Soil Genesis and Profile Development.....	40
Exercise A: Soil Monolith Description.....	46
Study Questions	48
Lab #5: Soil Survey and Soil Mapping.....	49
Exercise A: Use of a County Soil Survey Report	54
Lab #6: Land Evaluation.....	56
Field Worksheet	57
Land Evaluation	59
Washington Land Judging Score Card	60
Lab #7: Soil Fertility and Management Soil Testing → NO ₃ – N Content of Soils.....	61
Theory of Colorimetric Analysis	62
Soil Nitrate – Nitrogen Theory of Chromotropic Acid Method	63
References.....	65

INTRODUCTION

The Soil Science Laboratory Manual was made possible through a collaborative effort of Washington State Community and Technical College (CTC) faculty and the Agriculture Center of Excellence. The Agriculture Center of Excellence is one of eleven Centers of Excellence in Washington State. Centers are flagship institutions that build and sustain Washington's competitive advantage through statewide leadership. Each Center focuses on a targeted industry that drives the state's economy and is built upon a reputation for fast, flexible, quality education and training programs. The Agriculture Center of Excellence focuses on responding to workforce training needs and education in an industry that includes rural, urban, and related agriculture support organizations. The Center is a central hub to collect and disseminate the most current agricultural training services.

In 2006, the Agriculture Center of Excellence facilitated discussions with CTC faculty across the state about common courses among multiple degrees and disciplines. Basic Soil Science was identified as one of those courses. Additional conversations with CTC faculty who taught Soils Science determined core topics included in soils courses taught in the CTC system and Washington State University. The CTC faculty found that the development of a common Soil Science Laboratory Manual would be beneficial. The Center then contracted with Jerry Kjack, Instructor and Agriculture Department Chair, at Walla Walla Community College to compile the soil science labs that are found in the manual. Jerry holds an MS from Washington State University in Agronomy and has served as the lead soil science instructor at Walla Walla Community College since 1975.

The Agriculture Center of Excellence supports educational efficiencies, curricula sharing, and the integration of common courses among multiple degrees. The purpose of the Soil Science Laboratory Manual is to streamline curricula sharing, promote consistency across disciplines, and provide applicable materials for CTC faculty and additional educational partners, such as high school educators.

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Funding for this project provided by the Washington State Board of Community & Technical Colleges.

MATERIALS LIST FOR SOILS LABS

Lab #1: Soil Morphology

- A. Soil samples of variable texture
- B. Mortar and pestle (or similar device to remove aggregates from soil samples)
- C. Water bottles
- D. Examples of soil structural units (peds)
- E. Munsell Soil Color Charts

Lab #2: Soil Texture, Density, Porosity

- A. Gram scales
- B. Soil Mixer / Dispersion cups
- C. Bouyoucos cylinders
- D. Soils hydrometer
- E. °C thermometers
- F. 100ml graduate cylinders
- G. Dispersing agent – Sodium Hexametaphosphate

Lab #3: Cation Exchange and Soil pH

- A. Soil samples of various texture
- B. Plastic measuring cups – approximately 50ml.
- C. Distilled water
- D. Ca Cl₂ solution
- E. pH meter
- F. Funnels and test tubes
- G. KCl solution
- H. Filter paper
- I. Ammonium Oxalate solution
- J. Dropper bottles

Lab #5: Soil Survey and Soils Mapping

- A. County Soil Survey report
- B. Access to computers and internet connections

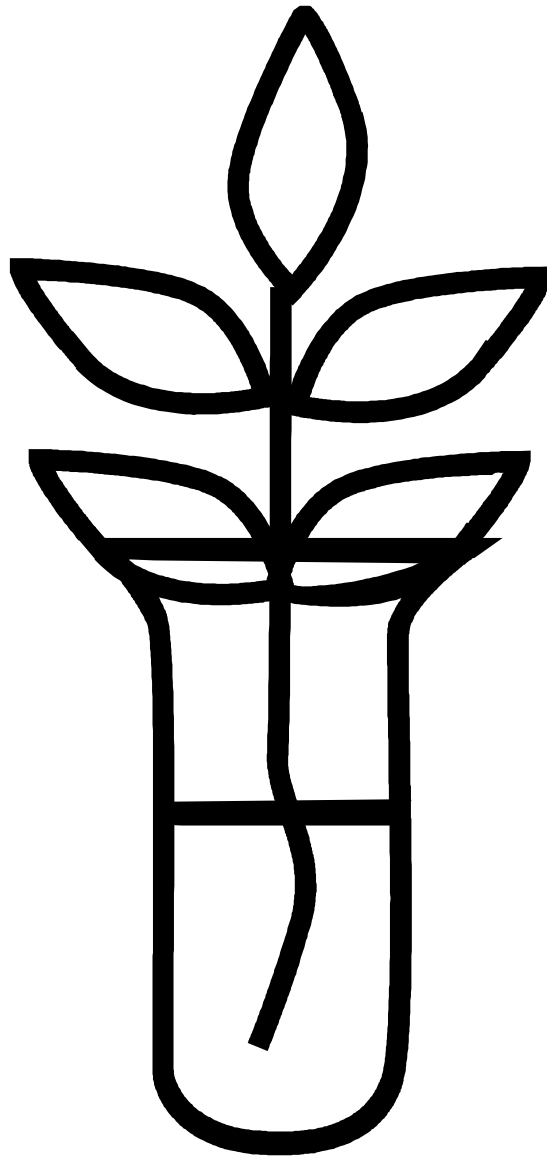
Lab #6: Land Evaluation

- A. Water bottles
- B. Abney Levels or similar slope measuring device
- C. Land judging manuals
- D. Rulers to evaluate profile/horizon depth
- E. Stakes for delineating parameters of site
- F. Soil pits – need to expose > 40” of soil profile

Lab #7: Soil Fertility and Management Soil Testing NO₃ –N

- A. Soil samples
- B. Light Colorimeter – Spectronic 20 is one used in most labs
- C. Reagents: Distilled water Ca SO₄ • 2 H₂O Antimony
Chromotropic Acid (disodium salt) Concentrated Sulfuric Acid
- D. Shaker / water bath

BASIC SOIL SCIENCE LABORATORY EXERCISES



LAB #1: SOIL MORPHOLOGY

Objectives

After completing this laboratory, the student should be able to:

1. Define the terms soil profile, horizon, texture, structure, and mottle.
2. Describe and use a systematic method for determining the textural class of a soil using the feel method.
3. Use the Munsell Color Classification System to classify a soil based on Hue, Value, and Chroma.
4. List five soil colors and give a possible cause for each color.
5. Explain the process and importance of mottling.

Introduction

The word **soil**, in a general sense, refers to all of the unconsolidated material occupying the earth's surface. Soil is a mixture of varying proportions of inorganic mineral and rock particles, living and dead organic matter, and voids or pores which contain variable amount of air and water. It develops at the interface between the atmosphere and lithosphere (bedrock), forming a blanket ranging in thickness from a few centimeters to two meters or more.

Soil is the medium from which most plants derive mineral nutrients and water. Soil also provides physical support for both plants and animals including humans and the structures they build. As you proceed through this exercise, keep in mind that a soil is not an inert, unchanging material. Rather, at any one time, a soil may be undergoing many simultaneous physical, chemical, and biological changes.

As implied, an individual soil body occupies a certain definite section of the landscape. Soils vary from one another in their properties and each has a unique internal organization. A **soil profile** is a single vertical cross section of soil extending from the surface into the underlying unweathered parent material. The soil profile is composed of **horizons** (horizontal layers of soil) which may be characterized by physical, chemical, and biological properties.

Horizons may be divided into major categories corresponding to the **surface soil** (O, A, and E horizons), the **subsurface soil** (B horizons), and the **substrate** (C and R horizons).

Three of the most basic physical properties used to describe soil profiles are **texture**, **structure**, and **color**. The following exercises are designed to give you some experience in describing these properties.

Soil Texture

Soil texture is concerned with the size of individual mineral particles. A major division in the size of soil particles is made at a particle diameter of 2 mm. Soil particles with a diameter greater than 2 mm belong to the **coarse fraction**, while soil particles less than 2 mm in diameter belong to the **fine earth fraction**. The fine earth fraction itself is divided into three main size separates (**sand**, **silt**, and **clay**), as follows:

Sand: 2.0 to 0.05 mm
Silt: 0.05 to 0.002 mm
Clay: less than 0.002 mm

It is unlikely that a soil will consist of mineral particles of a single size category. Normally a soil will contain some combination of sand, silt, and clay in addition to other organic and inorganic constituents. Soils having similar proportions of sand, silt, and clay are grouped into one of twelve textural classes. The textural triangle (Figure 1-1) was designed so that any combination of sand, silt, and clay could be placed in a textural class and assigned a name. You will learn to use the textural triangle during a later lab.

Exercise A: Determination of Texture by Feel

Many times it is necessary to estimate the textural class of a soil. The common field method for classifying soil texture is by feel. Much can be judged about the texture of a soil by merely rubbing it between the thumb and fingers. For example, a soil containing large quantities of sand will feel gritty when rubbed between your fingers. Silt has been described as having the feel of flour. A soil high in clay will be somewhat sticky (depending on the type of clay and the moisture content) and can usually be molded like modeling clay. Your lab instructor will discuss a systematic method for determining the textural class by feel and then help you "calibrate" your fingers using samples representative of several textural classes. Following this, try your hand at determining the textural class of the unknown soils provided. Don't get too discouraged, it takes considerable practice to consistently place an unknown soil in the correct textural class. Use the flowchart in Figure 1-2 and the clues in Table 1-1 to aid your determinations.

Unknown Soils

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

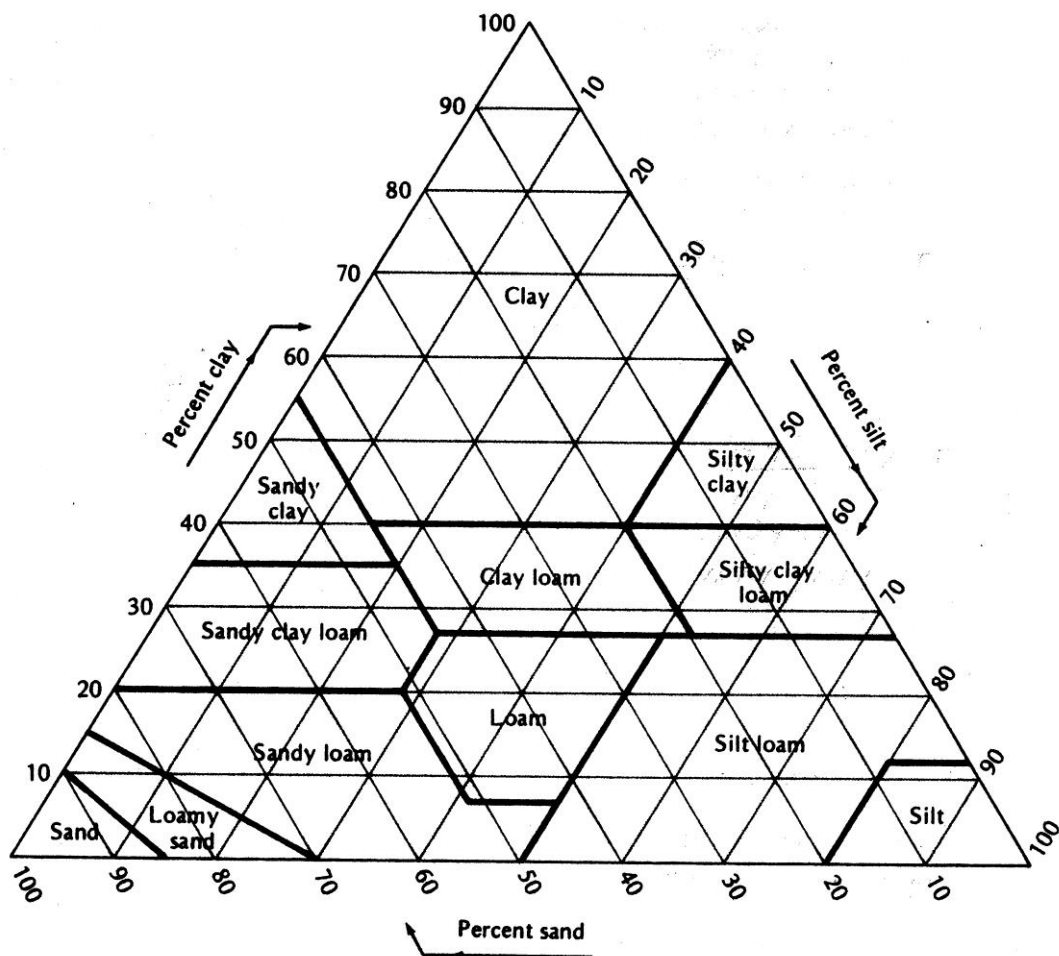


Figure 1-1. Percentages of sand, silt, and clay in the textural classes.

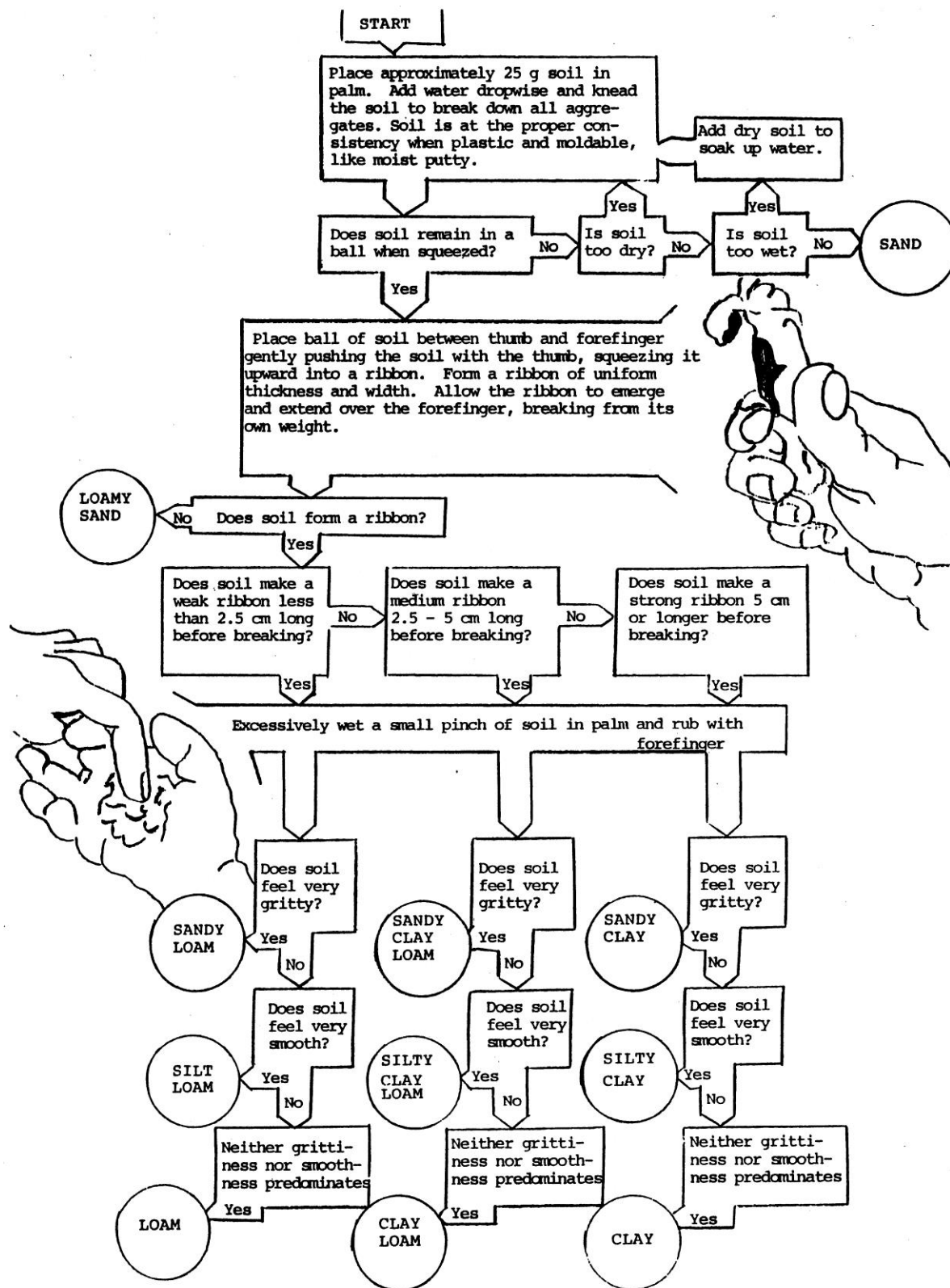


Figure 1-2. Determining soil texture by the "feel method".

Source: S.J. Thien, J. Agric. Ed. 8:54-55, 1979.

Table 1-1. Additional clues to the feel of textural classes:

SAND, LOAMY SAND

- Almost all sand
- Individual grains easily seen and felt
- Moist soil forms a cast that crumbles when squeezed

SANDY LOAM

- Sand dominates noticeably
- Moist silt forms a cast that can be gently handled

LOAM

- Can feel all three soil separates but none dominates
- Moist soil forms a cast that can be freely handled
- Cast may be squeezed to form short, broken ribbons

SILT LOAM

- Dry soil has both a smooth and gritty feel
- Forms a stable cast when moist
- Short, broken ribbons (<2.5 cm) may be formed

SANDY CLAY LOAM

- Feels very gritty yet moist soil will form a cast
- Medium ribbons (2.5 to 5.0 cm) may be formed

CLAY LOAM

- Moderate grittiness
- Medium ribbons (2.5 to 5.0 cm) may be formed

SILTY CLAY LOAM

- Feels smooth, little grittiness
- Medium ribbons (2.5 to 5.0 cm) may be formed

CLAY, SILTY CLAY, AND SANDY CLAY

- Often sticky, however, stickiness varies with clay type
- Long ribbons (>5.0 cm) may be formed
- Cast is often very tough to work between thumb and finger

Soil Structure

Soil structure is defined as the arrangement of individual soil particles (sand, silt, and clay) into larger aggregates called **peds**. The individual particles are held together by binding agents including organic matter, clays, calcium carbonate, and iron oxides. Peds are described in terms of their **type** (shape). Refer to Table 1-2 for further description of structure types.

Table 1-2. Description and location of soil structure types.

Structure Type	Aggregate Description	Common Location
Granular	Small and spheroidal peds	A horizon
Platy	Aggregates are thin, flat, and platlike	Compacted soils and E horizons
Angular Blocky	Block-like peds with sharply angled corners	B horizon
Subangular Blocky	Block-like peds with rounded corners	B horizon
Columnar	Column-like peds with rounded caps	B horizon
Prismatic	Column-like peds without rounded caps	B horizon

Exercise B: Soil Structure Types

Study the examples of structure types available in the lab. Also, examine several of the soil monoliths hanging on the lab walls. Try to identify all of the structure types listed in Table 1-2.

Soil Color

Color can provide soil scientists and land users with many clues about the genesis and mineralogy of a soil, provided the observers understand the causes for the various colors and are able to interpret the colors in terms of soil properties. Information concerning organic matter content, mineralogy, drainage, and aeration may be discerned from color and this information applied towards the management and potential uses of a particular soil. It should be stressed, however, that this information must be used with educated caution.

The colors of soil are derived largely from organic matter and minerals. Dark brown to black colors at or near the surface of a soil profile generally indicate the presence of **humus**, a heterogeneous organic colloid.

Soil color is markedly influenced by the oxidation state of iron. Yellow and reddish-orange colors in soil are often the result of ferric (oxidized) iron (Fe^{3+}). Thus, yellow and reddish-orange soil colors may indicate the soil is well drained and well aerated.

When the prevailing soil conditions are very wet and aeration is poor, ferric iron may be reduced to ferrous iron (Fe^{2+}). Soil minerals in this case may exhibit grey colors or subtle shades of blue. This phenomenon is often referred to as **gleying** by soil scientists. A grayish-blue coloration in the lower profile may indicate that the soil is saturated for most of the year and aeration is poor.

Iron present in poorly drained soils may also exist as flecks or spots of orange and yellow. This mottled soil color indicates a zone of alternate oxidizing and reducing conditions caused by seasonal fluctuations in the water table. The water table is usually at its highest point during the late winter, causing saturation of the lower portion of the profile. Iron is converted to the soluble ferrous form (Fe^{2+}) under these low oxygen (reducing) conditions. During the low rainfall season, the water table recedes and the availability of oxygen in the profile increases. Iron is converted to the insoluble ferric form (Fe^{3+}) under these high oxygen (oxidizing) conditions. The insoluble iron will deposit on ped surfaces as brightly colored iron oxides. The proximity of mottles to the surface of the soil indicates the approximate depth of the seasonally high water table.

Whitish-grey soil colors may be the result of several processes and explaining their presence depends largely on climatic considerations and the position of the color in the soil profile. Whitish-grey colors found near the surface, or overlying a clay layer, may indicate a zone of extensive leaching. This type of leaching frequently produces an **albic** horizon. If whitish-grey colors are found in a subsurface horizon of a soil receiving little rainfall, the color may be due to accumulations of lime (CaCO_3), gypsum (CaSO_4), or other salts. These horizons are commonly found in arid climates where there is insufficient moisture to leach to the soluble salts out of the profile. Lastly, in certain regions, whitish-grey colors may be due to deposits of volcanic ash.

Color is the sensation produced when light of a particular wavelength enters the human eye. Unfortunately, everyone does not perceive nor describe color in the same manner. The color of light is most accurately described by measuring it three principal properties, hue, value, and chroma. Hue refers to the dominant wavelength of the light. Value, also called brilliance, refers to the total quantity of light. It increases from dark to light colors. Chroma is the relative purity of the dominant wavelength of light. It increases with decreasing proportions of white light.

The **Munsell Color System** is a standardized color designation that specifies the relative degree of the three properties of color. The Munsell color notation can be quickly determined by comparison of a soil sample with a standard set of color plates. The color notation (e.g. 10 YR 6/2) can be translated into a more conventional color name. For instance, 10 YR 6/2 corresponds to the color name light brownish grey.

Exercise C: Soil Color

Your lab instructor will assign several soil samples to you. Describe the soil color of each horizon using your own terminology and then use the Munsell Color notation to describe the soil color.

Soil Color (your terminology) _____

Munsell Color Notation _____

Munsell Soil Color _____

Study Questions

1. List the three main components of soil texture. How might a person distinguish between them?
2. How does the texture of surface horizons compare with the texture of subsurface horizons?
3. When manipulating a moist soil sample, you observe noticeable grittiness, yet you are able to form a ribbon of 4 inches consistently. What is the probable textural class for this soil?
4. Which type of structure is most common in surface soil? What soil constituent is most important in the formation of structure in surface horizons?

5. What type(s) of structure are most common in subsurface soil? What constituents and/or processes contribute to the formation of structure in subsurface horizons?
6. What is the significance of structure to plant growth?
7. In general, how do surface colors compare with subsurface colors?
8. Name five soil constituents and the soil color you would expect them to be associated with.
9. What is the significance of mottles in making interpretations for soil use and management?

LAB #2: SOIL TEXTURE, DENSITY, AND POROSITY

Objectives

After completing this laboratory the student should be able to:

1. Distinguish between soil texture, structure, bulk density and particle density.
2. Use hydrometer and temperature data to determine the percent sand, silt, clay, and textural class for a soil sample.
3. Describe the relationship between soil texture, bulk density, particle density, and porosity.
4. Perform calculations involving bulk density, particle density, percent solids and percent pore space using the correct units and conversion factors.
5. Discuss the factors that can change the bulk density, particle density, and porosity of a soil.

Introduction

Soil is composed of solid material and pores. The solids are primarily mineral in nature, but also include living and dead organic matter. The pores contain variable amounts of water and air. The actual water content of soil pores depends on weather, irrigation, and several other factors.

A soil in good condition for plant growth will contain about 50% pore space and 50% solids (Figure 2-1). While it is sometimes helpful to think of the soil components separately, it should be emphasized that in natural soil the four main soil components are thoroughly mixed.

The relationships and interactions of the soil solids and pores are quite important and merit much study in soil science. The following exercises are intended to introduce you to some of these relationships. You will take a more detailed and quantitative look at soil texture. In addition, two additional properties, **soil density** and **porosity** will be investigated.

Soil Texture

Soil texture is defined as the relative proportions of sand, silt, and clay in a soil sample. Soil texture is important because it influences drainage, aeration, plant available water, ease of tillage, erosion, and the chemical and physical condition of the seedbed (Table 2-1). Soils that contain large quantities of silt and clay are said to be **fine textured** and are often referred to as **heavy** because they may be difficult to till. Sandy soils are said to have a **coarse texture** and are referred to a **light** as they are easily tilled and cultivated.

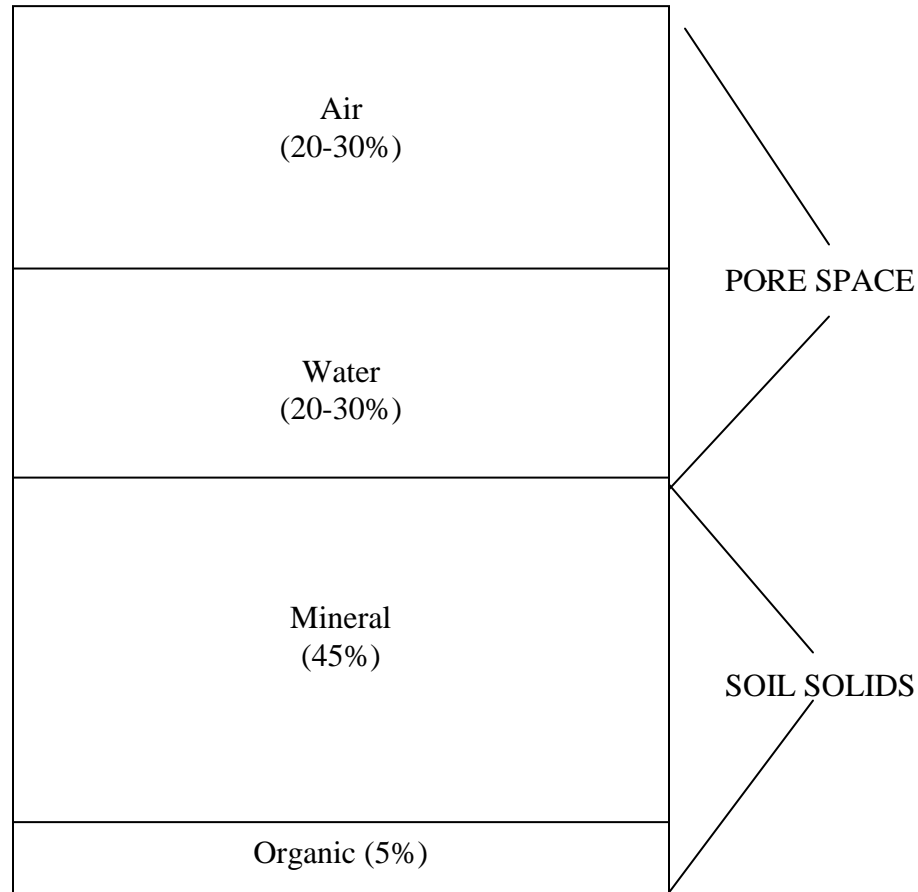


Figure 2-1. Volume composition of a typical silt loam surface soil.

Be aware that the terms light and heavy refer to ease of tillage and not to soil mass. As you shall see in the lab, the dry mass of a given volume of sand is actually greater than that of the same volume of clay.

Two methods exist for textural analysis, **particle size analysis** (mechanical analysis) and the **"feel" method**. Particle size analysis involves the use of a mechanical mixer to facilitate separation soil particles. The "feel" method involves an estimation of soil texture based on the feel of the sand, silt, and clay particles.

The particle size analysis procedure used in Exercise A, called the **Bouyoucos Hydrometer Method**, is based on two principles; dispersion and sedimentation. The soil sample is dispersed in water and the particle size distribution is determined by differences in sedimentation rates.

Table 2-1. A summary of textural effects on water relations, tillage, erosion, chemical, and physical relations.

	Sandy Soils	Loamy Soils	Clayey Soils
<u>WATER RELATIONS</u>			
Infiltration - entry of surface water into the soil	Rapid	Medium	Rapid if cracks present; very slow otherwise.
Percolation – internal drainage and leaching.	Excessive	Good	Fair to poor
Water Storage – stored in pores.	Very low	Medium	High
Aeration - movement of oxygen in to root zone.	Very good	Moderate	Good if cracks present; very poor otherwise.
<u>TILLAGE AND EROSION</u>			
Tillage Power Required - Drawbar pull	Low	Medium	High
Tillability - ease of seedbed preparation	Easy	Medium	Moderate
Erosiveness - wind	High	Low	Moderate
Erosiveness - water	Low	High	Low to medium
<u>CHEMICAL RELATIONS</u>			
Fertility Potential – nutrient retention	Low	Medium	High
<u>PHYSICAL RELATIONS</u>			
Surface Area	Low	Medium	High

Before a soil can be characterized on the basis of particle size, it is essential to overcome the tendency of the soil particles to cling together. Organic matter is one of the chief agents binding soil particles together. Thus, it is standard practice to oxidize the organic matter with hydrogen peroxide prior to beginning a particle size analysis.

Once the organic matter is removed, particle dispersion is achieved by stirring the sample with a mixer. This works well on the larger sand and silt aggregates, but is less effective on the smaller aggregated clay particles. Aggregation or clustering of clay particles is due in part to the presence of absorbed polyvalent (multicharged) cations such as Ca^{2+} and Mg^{2+} . Thus a chemical dispersing agent, sodium hexametaphosphate, is added to the sample. This treatment induces an exchange reaction between the polyvalent cations and the monovalent sodium ions (Na^+). Clay particles, when saturated with sodium ions, repel each other creating a dispersed condition. A mixture of dispersed soil particles in water is called a **soil suspension**.

Sedimentation rates of suspended soil particles depend primarily on particle size. Large sand-sized particles settle faster than smaller clay-sized particles. This relationship can be quantitatively expressed as **Stoke's Law**.

$$V = \frac{D^2 g (D_p - D_l)}{18 \eta} \quad \text{Eqn. 2-1}$$

Where:

- V = settling velocity (cm/s)
- d = diameter of the particle (cm)
- g = acceleration due to gravity = 980 cm/s²
- D_p = density of the particle
- D_l = density of the liquid
- η = viscosity of the liquid in poises (g/cm s)

To make Eqn. 2-1 more useful, several assumptions are normally made. The particles are assumed to be spherical with particle densities of 2.65 g/cm³. Also, the density and viscosity of the liquid are assumed to be constant, at a given temperature. This simplifies Stoke's Law to:

$$V = Kd^2 \quad \text{Eqn. 2-2}$$

Where K is a constant.

Eqn. 2-2 shows that the velocity of settling is directly proportional to the square of the particle diameter. In the lab, the number of particles at a selected point in a suspension at any one time can be measured with a **hydrometer**. A hydrometer measures the density (in g/L) of the suspension at the hydrometer's center of buoyancy.

G.J. Bouyoucos found that sand-sized particles (2.0 to 0.05 mm) settle out of suspension in 40 seconds. Silt-sized particles (0.5 to 0.002 mm) require approximately 2 hours to settle out of suspension. Therefore, after 2 hours, it is assumed that only clay-sized particles (<0.002 mm) remain in suspension.

Exercise A. Particle Size Analysis

1. Your instructor will assign a pre-weighed (50 g) oven-dried soil sample to you. Record the sample identification number on your data sheet.
2. Add 10 ml of 5% sodium hexametaphosphate to the soil in the dispersion cup and then add enough distilled water to bring the cup to about 2/3 of its capacity.
3. Stir the contents of the cup on a mechanical mixer for 4 minutes.
4. Quantitatively transfer the soil suspension into a Bouyoucos cylinder.
5. Carefully lower the hydrometer into the soil suspension. Add distilled water to bring the total volume (including the hydrometer) in the Bouyoucos cylinder to the 1130 ml mark.
6. Remove the hydrometer! Use the plunger to completely disperse the sediment at the bottom of the cylinder.
7. Carefully lower the hydrometer into the soil suspension. At precisely 40 seconds, record the hydrometer reading on your data sheet (NOTE: hydrometer readings are taken at the top of the meniscus). This reading represents your raw (uncorrected) %silt + %clay value.
8. Record the suspension temperature in degrees Celsius ($^{\circ}\text{C}$).
9. Repeat steps 6 and 7 twice more and record the hydrometer readings on your data sheet. You will use the mean of these three readings in your calculations.
10. Repeat step 6 but now place your Bouyoucos cylinder on the laboratory bench. Allow the cylinder to sit undisturbed for 120 minutes. While you are waiting for the 120 minute reading, you should estimate the texture of your unknown sample, using the feel method.
11. After 120 minutes, carefully return the hydrometer to the cylinder so as not to stir up the sediment. Record the 120 minute hydrometer reading on your data sheet.
12. Rinse the hydrometer and thermometer with distilled water and dry.
13. Proceed to the calculations section of this exercise.

Data Sheet

Soil sample identification _____

Soil weight (g) _____

40 sec. hydrometer reading (g/L) _____ Average _____

Temperature of suspension at 40 sec. ($^{\circ}\text{C}$) _____

Corrected 40 sec. hydrometer reading (g/L) _____ *

120 min. hydrometer reading (g/L) _____

Corrected 120 min hydrometer reading (g/L) _____ *

Percent sand _____

Percent silt _____

Percent clay _____

Estimated soil textural class _____

Calculated soil textural class _____

* See temperature correction formula on the following page.

Calculations

1. Correct your raw data for temperature using the following formula:

$$\text{Corrected reading (g/L)} = \text{hydrometer reading} + 0.36 (\text{temp.} - 20^{\circ}\text{C})$$

2. Use the following formulas to calculate the percent sand, silt, and clay in your sample. Determine the textural class using the textural triangle (Figure 2-2). How does this compare with your estimate of texture by feel?
3. Report your findings to the class by recording them on the chalkboard. Your laboratory instructor will summarize the class results with a brief discussion about the texture profile of this soil.

$$\% \text{sand} + \% \text{silt} + \% \text{clay} = 100\%$$

$$\% \text{silt} + \% \text{clay} = \frac{\text{corrected 40 sec. reading} \times 100}{\text{mass of dry soil}}$$

$$\% \text{clay} = \frac{\text{corrected 120 min. reading} \times 100}{\text{mass of dry soil}}$$

$$\% \text{sand} = 100 - (\% \text{silt} + \% \text{clay})$$

$$\% \text{silt} = 100 - (\% \text{sand} + \% \text{clay})$$

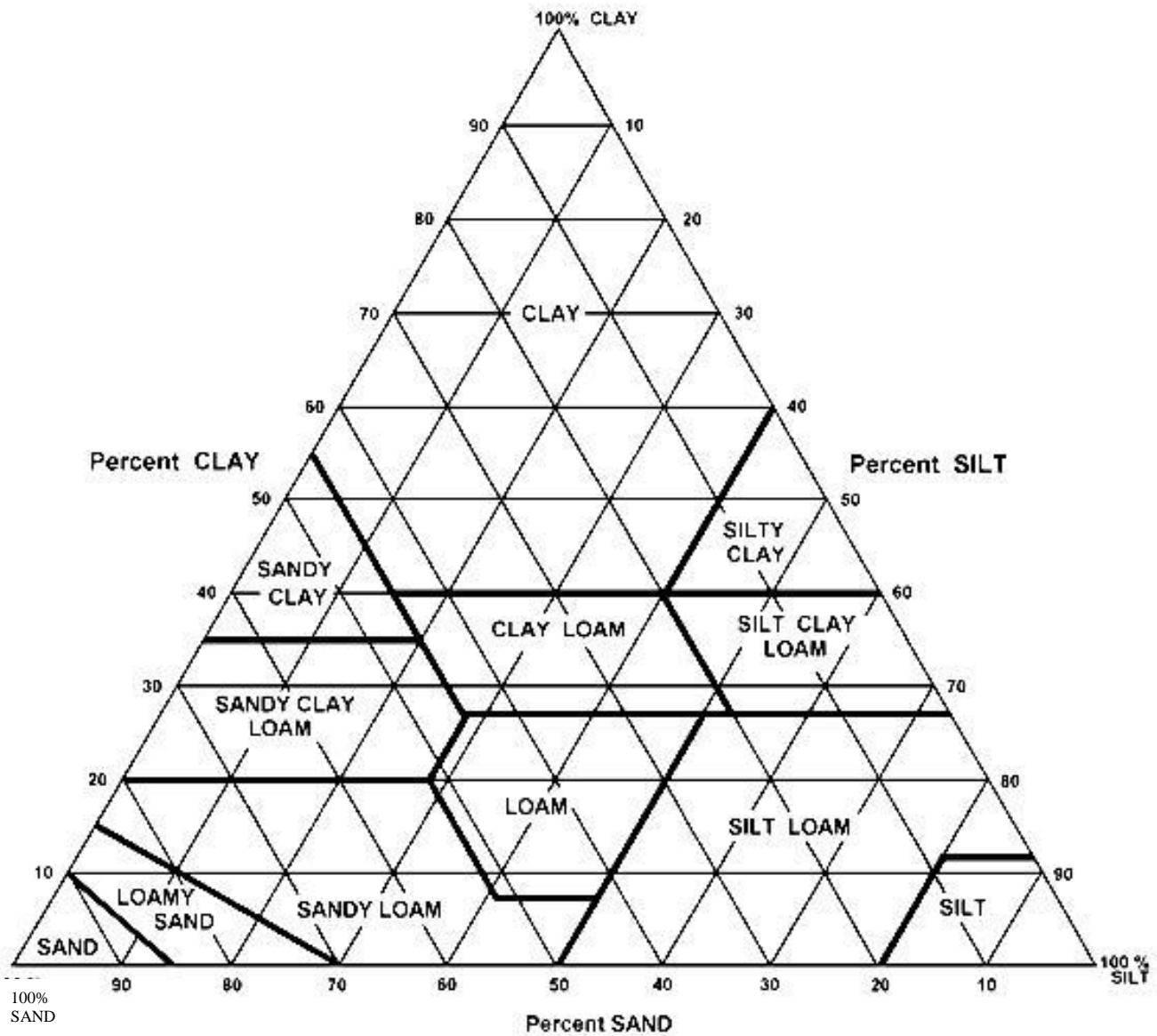


Figure 2-2. Textural triangle showing the percentage of sand, silt, and clay in the soil textural classes. To use the textural triangle, locate the percentage of clay first and project inward, as shown by the arrow. Do likewise for the percent silt (or sand). The point at which the two projections cross will identify the textural class name.

Soil Density and Porosity

The following exercises deal with the soil properties of density and porosity. A good understanding of soil density and porosity is essential to soil scientists, engineers, and persons involved in crop and timber production. Soil pores contain air for plant root metabolism and provide a compartment for water storage. Careful irrigation planning requires one to take into account the porosity as well as the initial moisture content of the soil.

Bulk density values provide an extremely useful conversion factor for calculations involving soil mass and soil volume. Bulk density measurements are also used to calculate the total pore volume in a soil as well as the weight of soil to be moved during an excavation. High bulk density values may indicate the presence of compact layers in soil that could restrict root and water penetration.

Within the subject of porosity, two concepts will be discussed, **total porosity** and **individual pore size**. The total porosity (total pore space) of a soil is that portion of the soil volume occupied by air and water. The amount or total volume of this pore space is determined largely by soil texture, structure, and organic matter content. A well-aggregated, fine-textured soil high in organic matter has a high total porosity, while a massive, coarse-textured or compact soil has a low total porosity.

Soil scientists generally describe two categories of individual pore size. Pores less than about 0.06 mm in diameter are considered **micropores** and pores with larger diameters are termed **macropore**. As you shall find in later laboratory exercises, individual pore size may have a profound influence on soil water movement and aeration.

The density of any object is its mass divided by its volume. Soil density is the dry mass per unit volume. This measurement is usually expressed in grams per cubic centimeter (g/cm^3) or megagrams per cubic meter (Mg/m^3). Soil has two densities, **bulk density** (D_b) and **particle density** (D_p). The difference between these two soil properties lies in the volume measured (Figure 2-3). Bulk density values represent the density of the soil as a whole, including solids and pore space. Particle density values represent only the mass per unit volume of the soil solids, pore space is not included. Soils containing a high proportion of pore space to solids have low bulk density values. Conversely, compacted soils with decreased pore space have a higher mass per unit volume ratio and higher bulk density values.

Particle densities for most mineral soils range from 2.60 to 2.75 Mg/m^3 . This relatively narrow range reflects the fact that quartz, feldspar, and silicates with densities near 2.65 usually comprise the majority of solids in mineral soils.

Soil organic matter, having a particle density of 1.1 to 1.4 Mg/m^3 , is much lighter than the soil minerals. Consequently, the higher the organic matter content, the lower the particle density. Thus, surface soil layers with high organic matter contents typically exhibit lower particle densities than do subsurface horizons. Bulk density values follow a similar trend. Increased bulk density values in subsurface soil are due to decreased organic matter, less aggregation and root penetration, and compaction caused by the weight of the overlying soil.

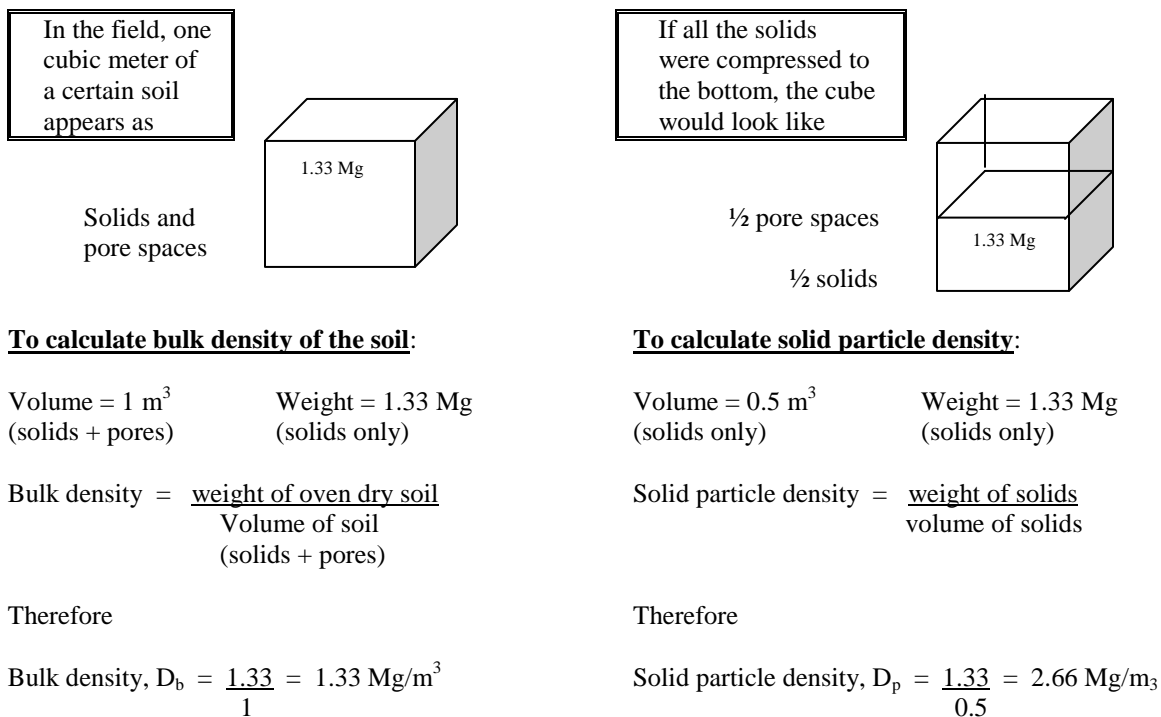


Figure 2-3. Comparison of soil bulk density and particle density.

Bulk density values are affected by soil texture and modified by structure. The large-sized particles in sandy soils tend to pack to fairly defined volumes which contain few micropores but many macropores. The small aggregated soil particles in a fine-textured soil tend to be separated by many micropores. However, in soils with well developed structure, large macropores may exist between the peds.

Bulk densities for mineral soils commonly range from 1.00 to 1.80 Mg/m³. Highly compact subsurface soils usually have high bulk density and low total porosity. In extremely compact soils, where the porosity is near zero, the bulk density value may begin to approach the particle density value.

The bulk density of clay soils tends to be much more dependent upon land management than does the bulk density of sandy soils. Incorporation of large amounts of organic matter will lower the bulk density of the surface soil. Organic matter is also extremely important in promoting aggregation, which maintains high porosity.

Tillage operations may have both favorable and unfavorable effects on bulk density and porosity. The short-term effects of tillage are generally beneficial as large clods are broken up and organic matter is returned to the soil. However, intensive cultivation over long periods of time may be detrimental to soil structure. Repeated mixing of the soil hastens the oxidation and loss of organic matter. Numerous passes over a soil with heavy farm equipment also may break down stable aggregates, increase compaction, and decrease porosity.

Soil density can be calculated in a number of ways, some are highly sophisticated. The principle to be used in the exercise is common to all methods; that is a measurement of the weight and volume of the soil. You will compare the bulk density, particle density, and porosity of two soils varying widely in texture. You will also contribute data to the determination of a **bulk density profile** for a fine-textured soil.

Exercise B. Measurement of Bulk Density Using a Soil Core

1. Your lab instructor will assign you a fine-textured soil sample. Record the identification number on your data sheet.
2. Determine the sample weight and record the value on the data sheet following this exercise.
3. Determine and record the volume of the sample ring, in cm^3 , using the following formula:

$$\text{Volume} = \text{Area} \times \text{Depth}$$

$$\text{Where: Area of a circle} = \pi r^2$$

(where r = the radius of a circle)

$$\text{Depth} = \text{depth of the sample ring}$$

4. Calculate the bulk density in g/cm^3 and Mg/m^3
5. Retain your sample for the next exercise!!!
6. Repeat steps 1 - 4 with the sandy soil

Exercise C. Measurement of Particle Density

1. Add water to an empty graduated cylinder to the 70 ml mark.
2. Transfer 40.0 g of the fine-textured soil into the graduated cylinder.
3. Remove trapped air by carefully tapping the cylinder on the lab bench.
4. Determine the volume of the soil-water mixture.
5. Calculate the particle density. Remember that the volume of interest for particle density calculations is the volume of the soil solids!
6. Use the following formula to calculate the percent pore space.

$$\%PS = (1D_b/D_p)100$$

Where: %PS = percent pore space
 D_b = bulk density
 D_p = particle density

7. Pour the contents of the cylinder into the buckets in the sink and rinse out any remaining soil material.
8. Repeat steps 1 - 7 with the sandy soil.

Data Sheet

Sample Identification _____

Exercise B:

	Fine-textured soil	Sandy-textured soil
Soil Weight (g)	_____	_____
Soil Volume (cm ³)	_____	_____
Bulk Density (g/cm ³)	_____	_____
Bulk Density (Mg/m ³)	_____	_____

Exercise C:

	Fine-textured soil	Sandy-textured soil
Soil Weight (g)	_____	_____
Soil Volume (cm ³)	_____	_____
Particle Density (g/cm ³)	_____	_____
Particle Density (Mg/m ³)	_____	_____
Percent Pore Space	_____	_____

Study Questions

1. It is standard practice to take a 2 hour hydrometer reading during the particle size analysis procedure. If a 90 minute reading was taken, how might the calculated results differ from the true soil separate values?
2. Imagine you are able to measure the surface area of all mineral particles in a cubic centimeter of soil. Which would have the greatest surface area, a clay or a sand? How does this relate to the total pore space of both soils?
3. Is it practical to attempt to modify the texture of a soil being used for field crop or forest production? Why or why not?
4. How are bulk density values influenced by soil texture? Soil structure?
5. What is the influence on soil bulk density and porosity of:
 - a. Additions of organic material?
 - b. Short-term tillage?
 - c. Long-term tillage?
6. How do bulk density values change with profile depth? What factors are responsible for bulk density values in the surface horizon? What factors are responsible for bulk density values in subsurface horizons?

7. What generally is the relationship between total pore space and soil texture? Between individual pore size and texture?

8. The following data were obtained:

Weight of wet soil = 70.5 g
Weight of dry soil = 62.5 g
Volume of water before adding soil = 70 ml
Final volume of soil-water mixture = 93 ml
Total soil volume = 40 cm³

- a. Calculate the bulk density.
- b. Calculate the particle density.
- c. Calculate the percent pore space.

9. Calculate the volume in cm³, of a soil sample weighing 200 g. Assume the bulk density is 1.33 Mg/m³.

10. a. Calculate the bulk density of a soil having a total porosity of 45%. Assume the particle density is 2.65 Mg/m³.

b. Calculate the total volume and the volume of solids in 250 g of the above soil.

BULK DENSITY

SOIL WEIGHT - 4 grams

SOIL VOLUME - 2.6 cc

What is B.D. ?

What is Porosity?

$$\text{B.D.} = \frac{4 \text{ g}}{2.6 \text{ cc}} = 1.54 \text{ g/cc}$$

$$\text{Porosity} = 1 - \frac{\text{B.D.}}{\text{P.D.}} \times 100$$

$$1 - \frac{1.54}{2.65} \times 100$$

$$1 - .58 \times 100$$

$$= 42\%$$

If soil porosity = 47%
What is B.D. of soil?

$$1 - \frac{X}{2.65} = .47$$

or

$$.53 = \frac{X}{2.65}$$

$$.53 \times 265 = 1.40$$

BULK DENSITY

$$\text{Bulk Density} = \frac{\text{Weight of Soil}}{\text{Volume of Soil}}$$

Example:

$$\text{Weight} = 2.66 \text{ grams}$$

$$\text{Volume} = 2 \text{ cubic centimeters}$$

$$\frac{2.66 \text{ g}}{2 \text{ cc}} = 1.33 \text{ g/cc} = \text{Bulk Density}$$

PARTICLE DENSITY

Pore Space

Solids

Soil Mass
(solids and pore space)

$$\text{Particle Density} = \frac{\text{Weight of Soil Mass}}{\text{Volume of Solids Only}}$$

Example:

Weight of Soil Mass = 2.66 grams

Volume of Solids Only = 1 cubic centimeter

LAB # 3: CATION EXCHANGE & SOIL ACIDITY

Objectives

After completing this laboratory, the student should be able to:

1. List and explain three sources of negative charge on soil colloids.
2. List and explain three factors influencing the magnitude of cation exchange capacity in soil.
3. Write a balanced cation exchange equation for a reaction between a soil colloid and the soil solution.
4. Explain the terms active acidity, exchangeable acidity, base saturation and soil buffering capacity.
5. List and explain four factors contributing to soil acidity.
6. Perform cation exchange calculations involving cmol (+)/kg and atomic mass data.

Introduction

The management of land for many practical uses, in particular agriculture, requires controlling and manipulating the chemistry of soil. Fundamental to the understanding soil chemistry is the study of soil colloids.

The clay and humus fractions of the soil are primarily made up of colloidal particles. Colloidal particles are extremely small (0.2 to 0.001 μm in diameter), exhibit a large surface area per unit weight and, in soil, usually exhibit a net negative charge. There are three sources of negative charge on soil colloids:

1. isomorphous substitution
2. exposed crystal edges of silicate clays
3. carboxylic and phenolic groups on humus

Isomorphous substitution is a permanent charge of soil colloids. Negative charge associated with exposed crystal edges, carboxylic, and phenolic groups is pH dependent (variable). This pH dependent charge increases with increasing soil pH. An important result of the net negative charge is that soil colloids can attract and retain positively charged ions (cations). **Adsorption** is the term used to describe the electrical attraction of ions to a charged surface.

Cation Exchange

Adsorbed soil cations are held very weakly by soil colloids. The weak nature of this attraction allows an adsorbed cation to be easily replaced by another cation. **Cation exchange** is the process of cations in solution exchanging places with adsorbed cations. The **exchange complex** refers to all particles like clay and humus that contribute to cation exchange in soil.

Figure 3-1 illustrates an idealized exchange reaction between calcium in the soil solution and adsorbed hydrogen ions. This reaction is oversimplified for the sake of illustrating the basics of cation exchange. Remember that a real soil system contains a great abundance and variety of cations on the exchange complex and in the soil solution.

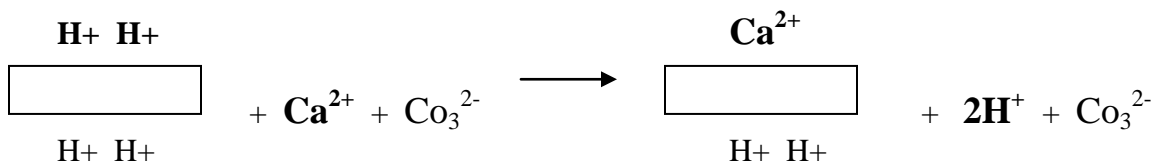


Figure 3-1. A simple cation exchange reaction involving a calcium ion in the soil solution and hydrogen ions on the exchange complex.

Perhaps the most important chemical property of a soil is its ability to retain and exchange cations. The **cation exchange capacity (CEC)** of a soil is defined as the total amount of exchangeable cations held by a given mass of soil. Cation exchange capacity is expressed in terms of moles and positive charge per unit mass. For the convenience of being able to express CEC in whole numbers, the accepted unit of CEC is **centimoles of positive charge per kilogram of soil (cmol(+)/kg)**.

The magnitude of CEC in soil can be related to several soil components including the type and amount of clay and humus content. CEC values range from about 2 to 100 cmol(+)/kg in mineral soils. Peat soils may have CEC values as high as 200 cmol(+)/kg. The cation exchange capacities of several soil components are given in Table 3-1.

Table 3-1. Approximate cation exchange capacities of selected soil components.

Component	CEC (cmol(+)/kg)
Humus	200
Vermiculite	150
Smectite	100
Illite	30
Kaolinite	8

In addition to clay and humus, soil pH influences the magnitude of CEC in a soil. The CEC of most soils increases with pH (Figure 3-2). This **pH dependent charge** is due to deprotonation (dissociation of hydroxyl (-OH) and carboxyl (-COOH) groups on organic and clay colloids.

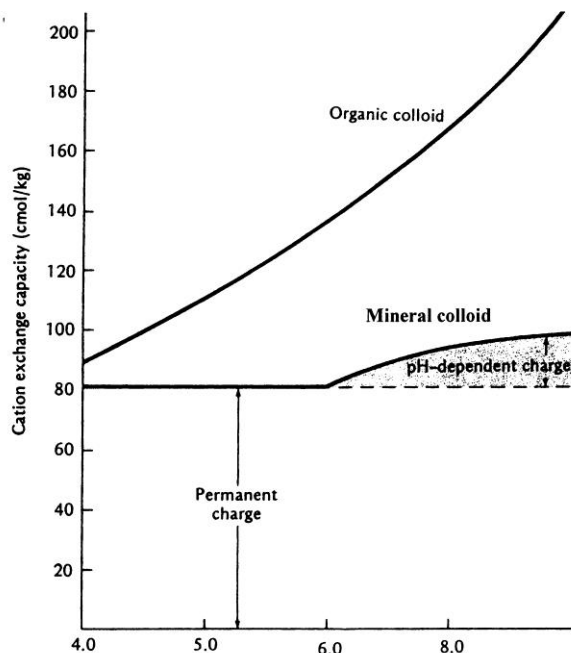


Figure 3-2. Influence of pH on the cation exchange capacity organic and mineral colloids.

Through cation exchange, soil colloids greatly increase the retention of plant nutrients such as calcium, magnesium, potassium, and ammonium. These nutrients are partially protected from leaching, yet are readily available for plant consumption. To a certain extent, the greater the CEC, the greater the long-term fertility of a soil.

Most colloids in soils act as a "giant anion" in cation exchange reactions. However, positively charged colloids do exist, particularly in acidic soils high in hydrous oxides of Fe, Al, and Mn. In this case, **anion exchange** reactions may occur.

Adsorption and exchange of ions implies that the material doing the adsorbing or exchanging must be charged. To determine the sign of charge on soil colloids, use may be made of organic dyes that are composed of colored ions. **Gentian violet** has a purple-colored cation while **erythrosine** contains a red-colored anion. Comparing the reaction of these two dyes with soil provides a qualitative means of determining the sign and relative magnitude of net electrical charge.

Soil Acidity

Soil acidity, also called soil reaction, is described in terms of pH values. Soil pH is a measurement of the hydrogen ion concentration of the soil solution. The amount of hydrogen ions present in the soil solution represents **active acidity**. As is indicated in Figure 3-1, cations in the soil solution are in equilibrium with cations adsorbed on the exchange complex. The amount of acidic cations retained by the soil colloids is called the **exchangeable** or **reserve acidity**.

When the pH of a soil is reported, the method used to measure the pH should also be specified. This is because some methods measure only the active acidity while others measure both active and exchangeable acidity.

Measurement of pH is one of the most common tests performed on soil. This is because pH directly and indirectly influences many soil processes. Acidity itself can restrict the growth of acid-intolerant plants. Microbial activity is also affected by pH. In addition, the solubility of many plant nutrients is significantly influenced by soil pH (Figure 3-3). For example, P, K, S, and Ca are less soluble and more likely to be deficient in acid soils. On the other hand, the solubility of Fe, Mn, B, Cu, and Zn are greatly increased at low soil pH. Some of these nutrients may actually become soluble to the point of plant toxicity. A close examination of Figure 3-3 indicates the range of maximum nutrient availabilities is about pH 6.5 to 7.5.

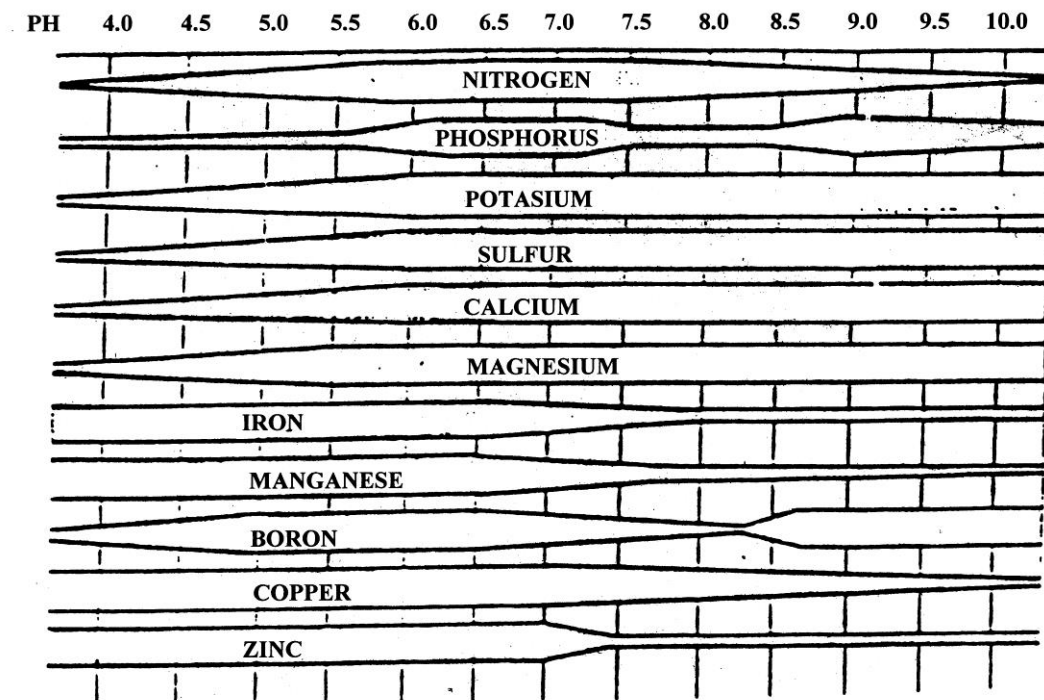
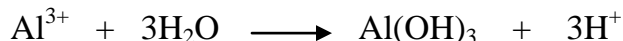


Figure 3-3. The general relation of pH to the availability of plant nutrients in soil. The wider the bar, the more available is the nutrient.

Several factors are known to contribute to soil acidity. Prolonged leaching favors the accumulation of hydrogen in solution and on the exchange complex. The normal **biological activity** of soil produces organic acids such as H_2CO_3 . The process of nitrification releases hydrogen ions. **Acid rain**, a growing environmental problem in the U.S. and abroad, brings about the input of stronger acids, such as HNO_3 and H_2SO_4 .

As conditions become acidic, increased soil weathering occurs. The weathering of aluminosilicates (one of the building blocks of clay minerals) releases Al^{3+} into the soil solution. The increased concentration of Al^{3+} in solution has three major effects on a soil's chemistry. First, Al^{3+} readily replaces adsorbed plant nutrients like Ca, Mg, and K thereby increasing their susceptibility to leaching. Second, Al^{3+} contributes to the production of hydrogen ions via a **hydrolysis reaction**:



Thirdly, high concentrations of soluble and exchangeable Al can be extremely toxic to plants.

You have already been introduced to the concept of soil cation exchange capacity. The CEC is the total amount of exchangeable cations expressed as centimoles of positive charge per kilogram of soil. The CEC can be partitioned into the amount of exchangeable **acidic cations** and the amount of **basic cations** present on the exchange complex.

The percent exchangeable acidity can be calculated as follows:

$$\% \text{ exchangeable acidity} = \frac{\text{exch. acidic cations (cmol (+) /kg)}}{\text{CEC (cmol (+) /kg)}} \times 100$$

Where: acidic cations = the sum of exchangeable H^+ and Al^{3+}

Related to the percentage exchangeable acidity of the soil is the concept of **base saturation**. The percentage base saturation can be calculated by the formula:

$$\% \text{ base saturation} = \frac{\text{exch. basic cations (cmol (+) /kg)}}{\text{CEC (cmol (+) /kg)}} \times 100$$

Where: basic cations = the sum of exchangeable Ca^{2+} , Mg^{2+} , K^+ , and Na^+

The base saturation is important in soil fertility and soil classification work. For example, maximum alfalfa yields require a base saturation of 65% or greater. Additionally, to be classified as a Mollisol, the surface horizon of a soil must have at least 50% base saturation.

Many soils tend to resist changes in pH due to the dynamic equilibrium existing between exchangeable and active hydrogen ions. When soluble hydrogen ions are neutralized by lime applications the equilibrium is upset. Exchangeable hydrogen ions dissociate from colloidal surfaces to replenish the supply of soluble (active) hydrogen ions. This process illustrates the **buffering capacity** of soil. Buffering capacity is a property of any weak acid, including a soil colloid, which partially dissociates and donates hydrogen ions. Most of the hydrogen ions in an acid soil are retained in the exchangeable form. The higher the CEC of a soil, the greater will be its potential buffering capacity.

Exercise A: Measurement of Soil pH

1. Fill two plastic cups approximately half-full with clay loam. Use 20 grams of soil.
2. Add 30 ml distilled water to cup #1 to make a saturated soil paste. Your lab instructor will demonstrate the preparation of a saturated soil paste.
3. Add 30 ml 1.0 N CaCl_2 to cup #2 to make another saturated soil paste.
4. Let the saturated soil pastes stand for at least 20 minutes. Determine the pH of each paste with a pH meter and record the values on your data sheet.

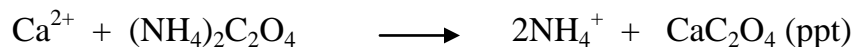
Data Sheet

pH of dH_2O paste _____

pH of CaCl_2 paste _____

Exercise B: Cation Exchange in an Acidic Clay Loam Soil

1. Prepare two funnels for filtration. Place clean, numbered test tubes beneath the funnels.
2. Place two tablespoons of the clay loam in the funnels. Make a small depression in the center of each soil so that added liquid will go through the soil and not down the sides of the filter paper.
3. Slowly add 30 ml of 0.2 N KCl solution to funnel #1 and collect one-fourth of a test tube to filtrate.
4. Slowly add 30 ml of distilled water to funnel #2 and collect one-fourth of a test tube of filtrate.
5. Test for calcium in each filtrate by adding 5 drops of saturated ammonium oxalate to each test tube. The formation of a cloudy white precipitate (calcium oxalate) indicates the presence of calcium in the filtrate.



6. Record your observations on the data sheet describing the turbidity (cloudiness) as high, medium, or low.

Data Sheet

Turbidity: Distilled water _____

0.2 N KCl _____

Study Questions

1. Explain the general relationship between CEC and soil texture. Does a similar relationship exist between CEC and the humus content of a soil? Explain your answer.
2. Write a balanced cation exchange equation for the reaction of the gentian violet dye with the clay soil. Assume the soil to be initially acidic and use the abbreviation $Gv^+ Cl^-$ for the dye.
3. Suggest a possible means of recovering the gentian violet dye molecules from the clayey soil.
4. When the soil was leached with the KCl solution, calcium was found in the leachate. However, when the soil was leached with distilled water, only a small amount of calcium was found. What does this suggest about the form (solid phase or solution phase) of calcium in this soil?

5. Sandy soils usually are thought to have a lower natural fertility status than clayey soils. Defend or refute this statement using the concept of cation exchange capacity in your answer.

6. Nitrate pollution of groundwater is a major environmental concern today. Leaching of nitrate-based fertilizers is believed to be one of the nitrate sources. Why are nitrate susceptible to leaching in soils?

7. What is the difference between adsorption and absorption?

8. What is the difference between active and exchangeable acidity? How are each of these soil properties measured?

LAB #4: SOIL GENESIS & PROFILE DEVELOPMENT

Objectives

After completing this laboratory, the student should be able to:

1. Outline and describe the general weathering processes in soil.
2. List the five factors of soil formation and explain the importance of each factor.
3. List the four processes of horizon development and give a specific example of each.
4. Relate specific factors of soil formation and horizon development to observable soil properties.
5. Sketch and label a soil profile including O, A, E, B, and C horizons and their properties.

Introduction

In Lab #1, you examined the morphology of a soil profile. The following exercises will introduce you to the factors responsible for soil genesis and profile development. You will also examine how these factors influence the appearance of a soil profile.

Weathering Process in Soil

The development of soils from original rock materials is a long-term process involving **physical** and **chemical weathering** along with biological activity. Weathering may be thought of as a combination of destruction and synthesis processes. The initial weathering action on the parent rock is physical in nature. Rock material is cracked and chipped, primarily due to temperature changes and frost action. These actions tend to reduce the size of the mineral particles present but do little to alter the chemical composition. As the size of the particles is reduced, the total surface area exposed to the environment increases which then increases the rate of chemical weathering processes.

Concurrent with physical weathering are the chemical processes of hydrolysis, hydration, acidification, oxidation, and dissolution. Thus the combination of physical (disintegration) and chemical (decomposition) weathering reduces the size of the rock fragments and changes the chemical composition of the resultant particles. Finally, the action of microorganisms and higher plant and animal life contributes organic matter to the weathered rock material and a true soil begins to form.

Weathering of rocks and minerals is the native source of plant nutrients. A general trend is for complex insoluble materials to be broken down releasing simpler more soluble products, in particular the macronutrient cations (Figure 4-1).

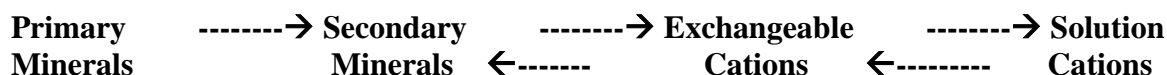


Figure 4-1. General outline of weathering process in soil.

Soil Forming Factors

The specific properties that a soil exhibits are determined by the type of the **parent material** from which the soil develops and the influences of **climate**, **topography** and **organisms** which act over **time** to transform or weather the parent material into a soil. The wide variation of soil characteristics observed in nature is due to the combined influences of these five **soil forming factors**.

The **parent materials** are the original rocks from which the soil evolves. The rocks may be igneous, metamorphic, or sedimentary. Two groups of inorganic parent materials are recognized: a) **sedentary** (formed in place) and b) **transported**, which may be subdivided according to agencies of transport and deposition.

The rate of weathering of the parent materials is determined primarily by the temperature and moisture regime of the environment (**climate**). The amount of water present during soil formation is important since the predominant chemical weathering reactions are either dependent on water as a medium for reaction or influenced by the quantity of water present. Temperature is important since the rate of most chemical reactions and biological processes increases with an increase in temperature.

The interaction of temperature and moisture causes different soils to form from the same parent material. For example, when a basaltic parent material is weathered, very different rates and types of soil formation can occur depending on the environment. If the climate is too hot and dry most of the year with only small amounts of rainfall occurring during the cool of winter (as on the Snake River Plain of southern Idaho), the rate of soil formation will be slow and the profiles shallow. If the climate were to change so that the rainfall increased and occurring during the hot part of the summer (as in the southeastern U.S.), then the rate soil formation would be much faster and the profiles much deeper.

In various locations where like combinations of the soil forming factors are found, it is expected that similar soils will form. For instance, the Miami loam (Figure 10-2) is a soil which results when the soil forming factors are: (1) a loam textured glacial till parent material, (2) a humid and temperate climate, (3) a well drained topographical position, (4) a hardwood forest vegetation

and (5) a period of time which approximates the time elapsed since the melting of the glaciers during the middle Wisconsin epoch. These conditions are fulfilled only in the states of Michigan, Wisconsin, Illinois, Ohio and Indiana. Hence the Miami loam soil is restricted to these geographic areas. If one or more of the five soil forming factors had been different, a different soil with different properties would have developed.

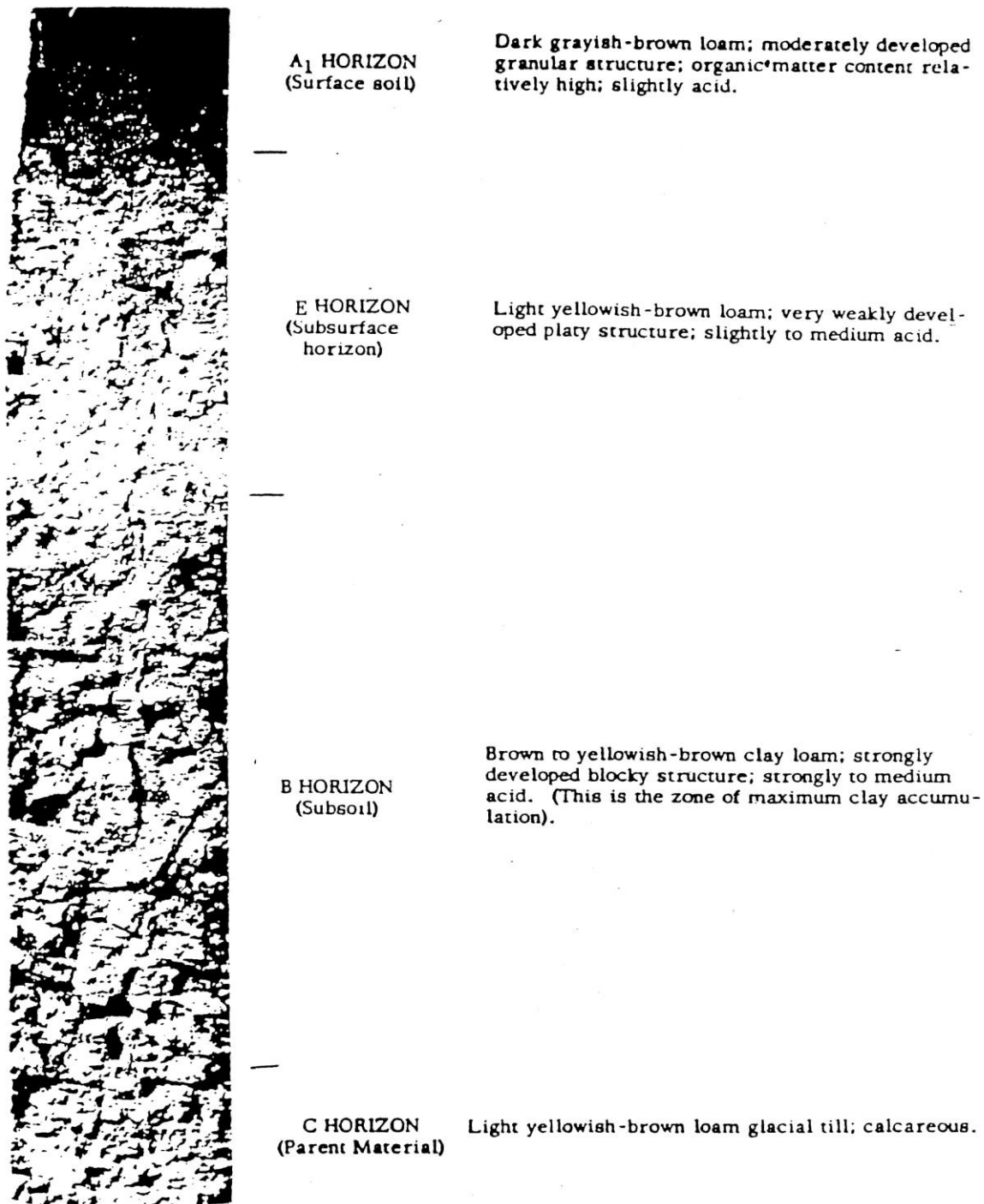


Figure 4-2. Soil profile of a Miami silt loam.

Development of a Soil Profile

Many factors are responsible for the unique morphology and internal organization exhibited by each individual soil profile. Horizon development may be categorized into four types of processes:

1. **Additions**
2. **Losses**
3. **Transformations**
4. **Translocations**

Many plants and animals find a habitat in soil and thus contribute to the organic fraction (**addition**). As soil microbes decompose organic matter, carbon is released as carbon dioxide (**loss**). Nitrogen is routinely converted from an organic to an inorganic form via the mineralization process (**transformation**). Further, organic matter is subject to movement from place to place in the soil by means of water and animal activity (**translocation**).

Mineral constituents undergo changes that may be similarly considered. Primary soil minerals weather with the simultaneous formation of secondary minerals which may then be moved from one horizon to another.

From the above discussion, you should begin to see that soil is not a static, inert body. On the contrary, soil is an **open, dynamic system**; the components of which are continually undergoing physical, chemical, and biological changes. The great diversity and variation exhibited by soils throughout the world may be attributed to differences in the intensity and length of time the processes of horizon development have operated.

The layers resulting from the soil forming and horizon development processes are grouped into six **master horizons** designated by the capital letters: O, A, B, C, and R.

Organic Horizons (O): Organic horizons form above the mineral soil due to the deposition of litter derived from dead plant and animal matter. These horizons are commonly observed in forested areas and are generally absent from grassland and cropland soils.

Eluvial Horizons (A, E):

(A): Topmost mineral horizon containing a strong admixture of humified organic matter which tends to impart a darker color than that of the lower horizons.

(E): Horizon of maximum leaching or eluviation of clays, primary minerals, and humus and corresponding concentration of resistant materials such as quartz. The E horizon is typically lighter in color than the A horizon.

Illuvial Horizons (B): Mineral horizons usually below the soil surface that are characterized as zones of maximum accumulation or **illuviation** of clays, primary minerals, and humus.

Thus a soil profile may be described in terms of combined master horizons and/or subordinate designators: Oe indicates an organic horizon containing organic matter of intermediate decomposition; AB indicates a transition between the A and B with properties more nearly like those of an A than of the underlying B, etc.

It should be evident that the profile of any one soil probably will not exhibit all of the possible horizons. Conditions of soil genesis will determine which horizons are present as well as the clarity of their expression.

Soils formed from the same parent material and climatic conditions can exhibit quite different profile characteristics if there are any differences in **relief** and **slope (topography)**. A sequence of soils thus formed is called a **catena**. Several catenas exist in the Palouse hills. Typical of these is the one depicted in Figure 4-3.

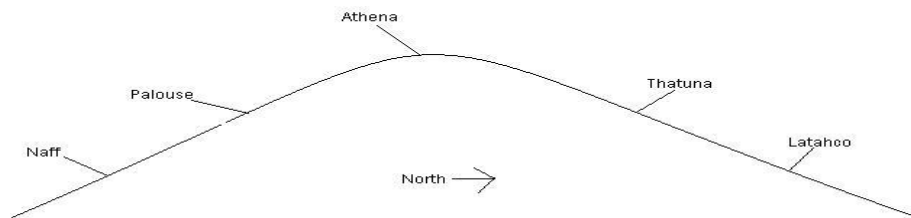


Figure 4-3. Diagram of a topographic catena found Palouse hills.

These soils are all formed from the same parent material, loess. Loess is silt-sized particles that have been transported and deposited by wind. Different soils have formed due to differences in relief and drainage. Typical profiles are given in Table 4-1.

Table 4-1. Typical profiles of a Palouse hills catena

Naff	Palouse	Athena	Thatuna	Latahco
Ap 0-7"	Ap 0-7"	Ap 0-7"	Ap 0-7"	Ap 0-7"
BA 7-16"	AB 7-15"	A 7-12"	AB 7-20"	A 7-14"
Bt 16-60"	BA 15-25"	AB 12-17"	B 20-33"	E 20-28"
	Bt 25-60"	BA 17-30"	E 33-39"	Bt 28-46"
		Bw 30-50"	Btb 39-60"	
		C >50"		

The wind action responsible for the loess deposition also caused the southern slope to be less steep than the northern slope on each hill. Snow blown onto the hills tends to accumulate on the

northern exposures. Additionally, the north slopes are exposed to much less sunlight than south-facing slopes. The combination of these factors causes higher effective moisture regime on the northern slopes as compared to the southern slopes. This causes the differences observed in the soil profiles.

All of the soils in Table 10-1 are Mollisols formed under grassland vegetation. The Athena series on top of the hills has a thick A horizon with grades into the B horizon. There is no increase in clay content in the B horizon; designation Bw indicates a color or structural B horizon. The Naff and Palouse series typically have plowed A horizons (Ap) overlying the Bt. The downward movement of water through the profile increases the clay content in the subsurface horizon.

On the northern slopes the increased moisture content and leaching causes an E horizon to form in the Thatuna profile it contacts the buried clay horizon (Btb). The permeability of movement decreases drastically causing the soil immediately above the Btb to become saturated. Since the northern slope of the hills is quite steep, the water will creep downhill along the top of the buried soil horizon. This phenomenon causes leaching of clays, minerals, and humus and eventually creates an E horizon.

Exercise A: Soil Monolith Description

Your instructor will assign two soil monoliths for you to describe. Using data sheets #1 and #2, sketch in the horizon boundaries and describe the soil color and structure of each horizon. Please note that the soil monoliths are very expensive and time consuming to produce. Please be extremely careful when working with the monoliths during this exercise.

Data Sheet 1 & 2

DATA SHEET 1

Soil Profile Descriptions

<u>Profile</u>	<u>cm</u>	<u>Properties</u>
0	0	
25	25	
50	50	
75	75	
100	100	
125	125	
150	150	

DATA SHEET 2

Soil Profile Descriptions

<u>Profile</u>	<u>cm</u>	<u>Properties</u>
0	0	
25	25	
50	50	
75	75	
100	100	
125	125	
150	150	

Study Questions

1. What are the general trends of texture, structure, and color within a soil profile?
2. Why do you think texture, structure, and color change with profile depth?
3. How does an E horizon form? A Bt horizon?
4. How do temperature and moisture influence soil development?
5. Given the same parent material, would you expect the soil to be deeper in a tropical climate or a desert climate?
6. Compare and contrast the profile properties of a forest soil and an agricultural soil.

LAB # 5: SOIL SURVEY & SOIL MAPPING

Soil Survey

The soil survey report is a U.S.D.A. publication normally available through your County National Resource and Conservation Service (N.R.C.S.) office. These written reports to include the soil maps have recently been converted to an on-line version at <http://soils.usda.gov/survey/>

I utilize both the written reports and the on-line version when teaching students to utilize the survey reports. I find that locating information within the on-line version can often be difficult and very time consuming compared to the written reports.

The following lab can be used with any county soil survey report by substituting your county for Walla Walla as utilized in the lab exercise.

Objectives

After completing this laboratory, the student should be able to:

1. Locate a quarter section of land on a soil survey map and determine soil association and most prominent soil series present.
2. Estimate the amount of area a mapping unit occupies in a given tract of land.
3. Distinguish between soil series and a mapping unit.
4. Locate and identify the potential uses and limitations of a particular soil using a soil survey report.
5. Locate and apply management information about a soil using a soil survey report.

Introduction

A soil survey is a record of occurrence of soil mapping unit on the earth's surface. In addition, a soil survey report contains much information and data about the use and management of soil for agricultural and non-agricultural needs. In other words, a soil survey report is an inventory of soils in a given area, usually a county, in which information about the uses, capabilities, and limitations of the soils in the inventory are included.

A soil survey report is written after the soils of an area have been mapped. Mapping involves the drawing of boundaries between soil series on a map of the area. The bounded areas of land are known as **mapping units**. To construct these maps, soil scientists must walk over the landscape, digging or boring holes to determine the profile characteristics. Information concerning overall

soil properties and management interpretations is also collected. Once all of the mapping information is summarized and analyzed, the manuscript portion of the soil survey report is written.

Each soil survey consists of two basic parts. The first consists of a written report giving information about various soils found in the area of study. Such information includes soil properties, management, and productivity. The second part of the report is a series of maps covering the entire area of study which show the location of the various soil series. In reality, these maps are prints of aerial photographs on which the soil scientist has marked the boundaries of the various mapping units, the mapping unit symbol, and other information.

Why are soil surveys made and survey reports written? This can be answered with two words, prediction and inventory. Using a soil survey report, an individual is able to predict the behavior of a soil without having firsthand experience with the particular soil. A soil survey provides a comprehensive source of information for a person unfamiliar with the soils in a given area. It should be stressed, however, that the information contained in the report is based on a **survey** of soils in a particular area. It is neither practical nor possible to evaluate every potential site in a survey area. Another consideration is that soils tend to be highly variable even over relatively short distances. Thus the information in a soil survey report is not site specific. Prior to making an important land use decision; an **onsite investigation** should be conducted to verify that predicted soil properties are actually present.

The purpose of this exercise is to improve your familiarity with the type of information contained in the soil survey report. To do this, you must first be able to locate a tract of land which is of interest to you. Once you have found a map of the land and have determined the soil mapping unit(s) present, you can use the written report as a source of management information.

The basis for location of a particular tract of land is the **Rectangular Survey System**. Before explaining the Rectangular Survey System, let's look at the system used by the thirteen original states, the metes and bounds method. The following is an example of this system.

“Begin at the middle of a large, white pine stump standing on the west side of Simon Vendor Cook's land and on the south side of the main road that leads to the new city, and there is also a fence that stands a little to the west of Simon Vendor Cook's barn, which said fence if it were to run cross the said field southerly, would run to middle of said stump; and running thence north 2 degrees east 19 chains and 50 links to a small white oak tree...”

* Source: C.L. Stewart and S.W. Vodker, The Mechanics of Land Transfer, Yearbook of Agriculture, 1958.

The obvious problem with this system is it is based on landmarks which are not permanent. Rocks, buildings, trees, etc. all can change or disappear with time. Therefore, the rectangular survey system was introduced and became the legal system for describing land in the U.S. in 1785.

Using the Soil Survey

The starting point of the rectangular survey is determined by the intersection of a survey line running east and west called a **base line** and another line running north and south called a **principal meridian** (Figure -1). There are 34 surveyed principle meridians in the U.S.

Lines parallel to the base line are surveyed every six miles to the north and to the south of the base line. These strips of land so divided are called **towns** (T). They extend east and west parallel with the base line. Other lines parallel to the principal meridian are surveyed every six miles to the east and west of the principal meridian. The strips of land so divided are called **ranges** (R).

Each town or range is designated by the distance it is from the base line or principal meridian. For example, the symbol T2N indicates that this town is in the area located 6 to 12 miles north of the base line. It is the second tier north of the base line. Another example would be the symbol R3W. This indicates that this range covers the area 12 to 18 miles west of the principal meridian or the third tier of land west of the principal meridian. (Figure 5-1).

By using towns and ranges, a region may be divided into square areas six miles on a side. Such areas are called **townships**. Townships are designated by both the town and range in which they lie. In Figure 5-1, the shaded area represents township T2N, R3W, of the principal meridian.

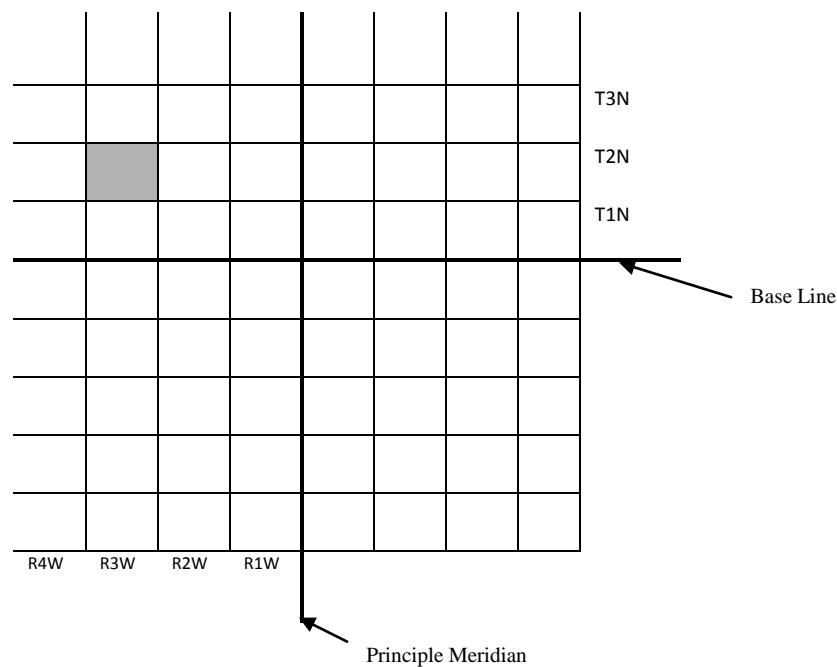


Figure 5-1. Illustration of the rectangular survey system

Each township is then subdivided into 36 square tracts of land, each being one mile on a side or 640 acres. Figure 5-2 is a diagram of a township divided into sections or square miles. Note the numbering system used to describe the sections in the township. Using this system, the darkened area in Figure 5-2 would have the legal description Section 15, T2N, R3W.

Further division of land to describe parcels less than 640 acres or one square mile is illustrated in Figure 5-3. Here section 15 above is divided into quarters. Each quarter is 160 acres and is described by its location in the section. Thus, if we are interested in the southeast quarter section of section 15, the legal description would be SE 1/4, Section 15, T2N, R3W. Other examples of subdivisions of a section are shown in Figure 5-4. Try to determine the legal description of each area.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Figure 5-2. The numbering of sections in a township.

NW 1/4	NE 1/4
SW 1/4	SE 1/4

Figure 5-3. The division of a section into quarters.

Further subdivisions are possible. For sites smaller than forty acres, the legal description may refer to the plat of the land which is located in the local County Recorder's office.

The rectangular survey system has one drawback. It imposes a rectangular system on a curved earth. Because of this curvature, systems are not always exactly one square mile. On the average, sections are about 50 feet shorter on the north edge than on the south. Every 24 miles (4 townships) a correction line is established parallel to the base line and the sections are again one mile on a side. This causes shifts in the range line as shown exaggerated in Figure 5-5.

A	E	F
	D	
	B	C

Figure 5-4. Examples of a subdivided section.

				T5N
				T4N
				T3N
				T2N
				T1N
R4W	R3W	R2W	R1W	

Figure 5-5. Correction of the rectangular coordinate system for earth curvature.

The deviations from the square that result from the earth's curvature are compensated for in a systematic manner. Sections 1 through 6 on the north side and sections 6, 7, 18, 19, 30, and 31 on the west side may be smaller or larger than 640 acres as required. All other sections are exactly 640 acres wherever possible.

Now let's examine the soil survey for Walla Walla County. Find the section, "How to Use the Soil Survey Report". Since you will be looking up many items, an idea of where to find these items is essential.

Next, read the sections, "How Soils are Named, Mapped, and Classified". You have already encountered many of the concepts described here. However, several new ideas are presented.

The next section of the report gives detailed descriptions of the **soil series**. Included in this section are discussions of profile characteristics, parent material, vegetation, topography, climate, capability class, and many items of information concerning the use of a particular soil.

The next section, "Use and Management of the Soils" discusses the types of information contained in the tables of the survey report. Areas of use and management covered include crops and pasture, woodland, recreation, wildlife habitat, and engineering properties. Also included in the tables section is the taxonomy of each soil series.

Before beginning today's exercise, your laboratory instructor will lead a brief discussion about the use of the soil maps.

Exercise A. Use of County Soil Survey Report

Answer the following questions using your Soil Survey Report. A quarter section will be assigned by your instructor.

Quarter Section Assignment: _____

1. On what map sheet will this tract of land be found?
2. Which mapping unit occupies the largest amount of acreage in this tract of land?
3. Approximately how much acreage does the mapping unit from question #2 occupy?
4. What soil series will be found in this mapping unit?
5. What is the capability unit of this series?
6. Why is the soil place in this grouping? (What is the limitation?)
7. What is the parent material for this soil?
8. What is the topographic position of this soil?
9. What is the average annual precipitation range for this soil?
10. What is the estimated permeability and water holding capacity of this soil?

11. What is the predicted pH range for this soil? Does it have a salinity problem?
12. What soil and/or water conserving practices are recommended to protect the land from soil erosion?
13. Which crops are suitable to be produced on this land according to the survey?
14. What is the suitability for road fill or gravel for this soil?

LAB # 6: LAND EVALUATION

Purpose

To be able to assess certain soil characteristics and topographic features of a field site and determine which soil and/or water conserving practices should be implemented to protect that site from water runoff and soil erosion.

Objectives

1. Determine soil texture by feel
2. Measure slope/relief of land with an Abney Level or similar device
3. Evaluate soil profile to include:
 - a. Depth of A and B horizons
 - b. Presence of any restrictions in profile
 - c. Presence of stones or other coarse mineral fragments
4. Evaluate surface cover/vegetation on site as it effects potential water runoff/soil erosion
5. Utilize the "Guide for Land Judging Contests" produced by the Washington Association of Conservation Districts.

This is designed to be a field exercise where students utilize the booklet to help them evaluate a site for potential use and management. The FFA organization utilizes this as a Soils Judging contest where students compete as teams for award purposes. In my college classes I do not require memorization of data, but rather concentrate on being able to evaluate soil characteristics and make recommendations on specific soil/water conservation practices based on feasibility and cost. I have included examples of information which would be furnished the participant on "site cards" since this is information they need but would not be able to determine while at the site. Also included is an example of a practice exercise and score card. I have students complete this prior to the field exercise to become familiar with what information they need to collect at the site and how to complete the card.

Field Worksheet

Location: Russell Creek Road

SITE CARD #1

Intended Use: Owner desires woodlot

Original topsoil depth – 36"

Never flooded

pH – 6.8

P – 8 ppm

K – 180 ppm

N – adequate

130 FFD

18" annual ppt.

SITE CARD #2

Intended Use: Wheat production

Original topsoil depth – 20"

Floods one in five years

pH – 5.6

P – 10 ppm

K – 130 ppm

N – deficient

150 FFD

16" annual ppt.

SITE CARD #3

Intended Use: Grazeable Pasture

Soil Test Results:

P – 15 ppm

K – 220 ppm

N – Deficient

Soil pH – 5.8

Frost free days – 110

Average annual ppt. – 19"

Thickness of original topsoil – 20"

Floods once in 15 years

Seasonably high water table at 46" below soil surface

Land Evaluation

CLASS EXAMPLE – TO BE TURNED IN FOR 20 POINTS

Site Card Intended Use: Grazeable Pasture

pH: 6.2

K: 240 ppm

P: 11 ppm

N: Deficient

Floods less than 1 in 10 years

Original topsoil: 24"

Average annual precipitation: 16"

Number of frost free days: 130

What you Measure or Evaluate

Topsoil: Find sandy loam

Subsoil: Silt loam

Topsoil Depth: 10"

A few 1" – 2" diameter stones in subsoil

Slope: 32%

Shale or bedrock material at 30" down in profile

Site has good stand of perennial grass

Scattered Rose/Hawthorne on site

WASHINGTON LAND JUDGING SCORE CARD			
Contestant No. _____		Field No. _____	
Part I Land Class Factors Indicate by an "X" in the circles by numbers		Part II Recommended Land Treatments Needed for different land capability classes	
Score		Score	
3 pts	A. SURFACE TEXTURE 0 1. Coarse 0 2. Mod. coarse 0 3. Medium 0 4. Mod. fine 0 5. Fine	15 pts	VEGETATIVE (Estb & Mgt) Use soil conserving and/or soil improving crops: 0 1. Every 4th or 5th year 0 2. Every 3rd or 4th year 0 3. Every 2nd year 0 4. Every year 0 5. Do not burn crop residue 0 6. Residue management, minimum tillage, and/or no till 0 7. Establish recommended grass 0 8. Proper pasture and range management 0 9. Protect from burning 0 10. Control grazing 0 11. Plant recommended trees 0 12. Harvest trees selectively 0 13. Use only for wildlife or recreation
3 pts	B. SUBSOIL TEXTURE 0 1. Coarse 0 2. Mod. coarse 0 3. Medium 0 4. Mod. fine 0 5. Fine	10 pts	MECHANICAL 0 14. Control brush or trees (mechanical or chemical) 0 15. Farm on contour/cross slope 0 16. Use divided slopes and/or strips 0 17. Construct level terraces 0 18. Install drainage system 0 19. Install grassed waterways and/or diversions 0 20. No mechanical treatment needed
4 pts	C. PERMEABILITY (Most restrictive layer) 0 1. Rapid 0 2. Moderate 0 3. Slow 0 4. Very slow	5 pts	FERTILIZER AND SOIL AMENDMENTS 0 21. Lime requirement test 0 22. Phosphate (P ₂ O ₅) 0 23. Potash (K ₂ O) 0 24. Nitrogen (N) 0 25. Fertilizer or soil amendments not needed
5 pts	D. DEPTH OF SOIL 0 1. Deep 0 2. Moderately deep 0 3. Shallow 0 4. Very shallow		
5 pts	E. SLOPE DRYLANDX IRRIGATEDX 0 1. 0-3 0-2 0 2. 3-8 2-5 0 3. 8-15 5-10 0 4. 15-30 10-15 0 5. 30-40 0 6. 40+		
4 pts	F. EROSION - WIND & WATER 0 1. None to slight 0 2. Moderate 0 3. Severe 0 4. Very severe		
4 pts	G. SURFACE RUNOFF (Not considered in land capability classification) 0 1. Rapid 0 2. Moderate 0 3. Slow 0 4. Very slow or ponded		
3 pts	H. SURFACE STONES 0 1. Stony 0 2. Nonstony		
4 pts	I. FLOODING 0 1. None 0 2. Rare 0 3. Occasional 0 4. Frequent		
5 pts	J. MAJOR FACTORS THAT KEEP AREA OUT OF CLASS I LAND 0 1. Surf.tex. 0 6. Surface rock 0 2. Perm. 0 7. Flooding 0 3. Depth 0 8. Other 0 4. Slopes 0 9. None 0 5. Erosion		
5 pts	K. LAND CAPABILITY CLASS 0 1. Class I 0 5. Class V 0 2. Class II 0 6. Class VI 0 3. Class III 0 7. Class VII 0 4. Class IV 0 8. Class VIII		
		SCORE PART I TOTAL (Possible 45) _____	
		SCORE PART II TOTAL (Possible 30) _____	
		TOTAL SCORE (Part I plus Part II) (Possible 75) _____	

LAB #7: SOILS FERTILITY & MANAGEMENT

SOIL TESTING → NO₃ – N CONTENT OF SOILS

Soil tests attempt to assess the fertility status of soils and in this way provide information useful in predicting fertilizer needs. Their importance is readily seen when one realizes that the current annual consumption of fertilizer in the United States is over 22 million tons and that the use of this fertilizer accounts for at least 25% of current crop production.

One of the most important features of a soil test is that it can be made weeks before the crop is planted so that fertilizers can be properly applied at planting time. Tests of green plant tissue and deficiency symptoms provide information only after the crop is growing. In this way their use for making fertilizer recommendations is considerably limited as the diagnosis of nutrient deficiency may occur too late in the season to be corrected with the addition of fertilizer. A discussion of some important soil testing principles is given to aid in understanding the requirements that must be met in order to have reliable soil tests and eventually good fertilizer recommendations.

Less than a pint of soil is used in making the common fertility tests. The results of the tests will be reliable only if the soil sample is truly representative of the field or area being tested. A sample which accurately represents the area tested is the *first requirement** of a successfully soil testing program.

The *second requirement* is an extracting solution which will extract all (or a proportionate part) of the available soil nutrients. Available nutrients are those in a condition which can be readily used by plants or those in a state that can be readily changed into forms suitable for plant use. Ammonium and nitrate ions are the forms of available nitrogen. In the case of phosphorus it is the more soluble compounds such as the calcium phosphates, colloidal adsorbed phosphate and a small portion of the organic phosphorus. The exchangeable potassium constitutes the major form of available potassium. Therefore it is important that the extracting solutions used be efficient in removing these fractions from the soil in order to obtain an accurate test.

The *third requirement* of a good soil test is that the amount of nutrient extracted must be correlated with the growth and response of crops in the environment under which the plants will be grown. A sound fertilizer recommendation can only be made when the amount of available nutrients in the soil, as determined by soil test, is correlated with the amount of fertilizer needed to obtain various yield levels.

The amount of fertilizer needed for a given amount of available nutrients varies with the environment and the crop to be grown. For example where moisture limits plant growth under dryland farming, a moderate amount of fertility will likely be sufficient as yields will tend to be

* Bray, R.H. Requirements for a Successful Soil Test, Soil Sci. 66:83-89.1989.

low. Under irrigation, this same land would probably need fertilizer to produce the most profitable yield due to the presence of adequate moisture. Secondly, cotton will require a different fertilizer recommendation than alfalfa when grown on the same soil because its nutrient needs are different.

Theory of Colorimetric Analysis

In the following exercise, you will use a colorimeter to measure the concentration of NO_3 in your extract solution. The colorimeter electronically evaluates the color that has been developed during the above exercise. The stronger the yellow color, the greater concentration of NO_3 in the solution. This is a simplified translation of the **Beer-Lambert Law**: the absorbance of light by a solution is directly proportional to the concentration of absorbing species when the path length is fixed. Mathematically, this is expressed as follows:

$$A = abc$$

Where:

A = absorbance

a = molar absorptivity

b = path length

c = concentration

The manner in which the instrument operates is quite simple. Light of a specific wavelength is directed through a sample tube which holds the sample solution. If the solution contains a chemical species that absorbs the particular wavelength of light, then the intensity of light transmitted by the sample is less than the intensity of light directed from the light source. The amount of light absorbed by the sample, the absorbance (A), can be related to the concentration of the absorbing species in the sample solution. Various chemical species absorb light of different wavelengths so, by selecting the appropriate wavelength, different elements can be evaluated with the colorimeter. A photodetector measures the amount of light that passes through the sample. Colorimeter values may be read in percent absorbance or percent transmission. Both of these values may then be related to the sample concentration using a standard curve.

1. Make sure instrument is “on” and the wavelength set at 400 nm. This is the wavelength associated with the maximum absorbance of nitrate in your extract solutions.
2. Rinse the sample tube several times with distilled water. This will reduce the chance of sample contamination.
3. Fill the tube with your sample and close the cover on the sample compartment.
4. Record the transmittance reading on your data sheet.
5. Repeat steps 3 and 4 using the same sample tube for all of your samples.
6. At this point, you should have transmittance recorded for each of your samples. Using these values, determine the amount of nitrate (in ppm) in your samples using the standard curve prepared by your instructor. Record these values on your data sheet.

Soil Nitrate-Nitrogen Chromotropic Aid Method

Reagents:

- A. .3% Antimony in 80% Sulfuric Acid. (Prepare this solution under vented hood.) Weigh 3.0 antimony into a 2-liter Pyrex reagent bottle. Add 300 ml conc. sulfuric acid. Put the bottle on a hot plate and heat until all antimony is dissolved. Remove from hot plate and cool. Add 500 ml conc. sulfuric acid and mix. Add 200 ml deionized water slowly and cool the mixture.

Note: This solution will recrystallize upon standing at room temperature overnight. Reheat solution before using.

- B. .02% Chromotropic Acid in Conc. Sulfuric Acid.
Weigh .05 g (.2 gm/liter) chromotropic acid (disodium salt) into a brown bottle. Add 2500 ml conc. sulfuric acid and mix.

- C. Soil NO₃ – N Extracting Solution
Dissolve 1.5 g CaSO₄·2H₂O in warm deionized water bring up to 1 liter volume.

Procedure:

1. Weigh 10 g of oven-dried soil into extracting rack. Add 25 ml extracting solution.
2. Shake for at least 15 minutes. Filter through acid-washed filter paper.
(Whatman #40 or VWR #74)
3. Pipet 1 ml of clear filtrate into a small (10 ml) colorimeter tube. Add 1 ml 0.3% antimony – 80% sulfuric acid. Mix solution on vortex mixer. Cool in cold water bath.
4. Add 2.5 ml .02% chromotropic acid-sulfuric acid solution. Mix and cool in cold water bath or air cool in dark place for at least 30 minutes.
5. Read %T on colorimeter at 400mu after at least 30 minutes.

Data Sheet

Sample #	Dilution Factor	Transmittance	PPM NO ₃ -N
1			
2			
3			
4			
5			

Standard Curve for NO₃-N:

Blank -- 100% Transmittance
2ppm -- 87.5% T
4ppm -- 86.4% T
6ppm -- 82.9% T
8ppm -- 73.7% T
10ppm -- 67.7% T

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