专业外语第一部分

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Chapter 1 Why Study Soils

1.1 Introduction

Few people in the U.S. workforce are soil scientists. However, each year many thousands of students and professionals find that some knowledge of soil is essential for success in their careers. What does one gain from studying soils? Some reasons for studying soil are described in this lesson.

1.1.1 Soil is an integral part of the ecosystem. Air, water and soil comprise the various ecosystems of the earth. A biome is a complex system of soil, climate and organisms. Soil is susceptible to pollution. We pollute soil by exposing it to human sewage, industrial waste products, agricultural and milling wastes, and natural contaminants. Soil is a medium where we grow what we eat, for example, cereals such as rice, wheat, corn…, vegetables such as tomato, potato, eggplant, onions, spring onions, spinach, and raw materials from which we can produce clothing, for example, cotton.

1.1.2 Soil is the domain of Archeology. Soils can reveal information about ancient climates, geology and peoples. Archeologist study ancient habitats, dwellings, and other cultural factors by examining soil. Often a buried topsoil holds a rich archeological find.

1.1.3 Soil properties affect engineering projects. To an engineer soil is earthy material that can be excavated with a shovel. Soil is construction material and typically is the natural foundation that supports the man-made foundation of a building. Soil properties limit engineering uses for a parcel of land. Soils may or may not be suitable for such uses as road beds, septic tank drain fields, dwellings with basements, or recreation facilities.

1.1.4 Soil is the primary resource for food Production. A subsistence diet requires about 400 lb (181 kg) of grain per person per year. This amount of grain production requires about 0.11 acres (0.045 hectares). An affluent, high-meat diet requires at least 4 times more grain (~.44 acres, 0.18 hectares) because the conversion of grain to meat is highly inefficient. Even cattle fed much of their life on pasture are typically fattened up in a feedlot where they are fed about 6 pounds of grain for every pound of weight gain. Of course much of this weight gain is not edible meat, and most of the meat weight is water. This inefficiency is exacerbated by market trends showing that chicken has now surpassed beef consumption. Chickens, of course, are not pastured at all. Trends indicate that within a few years pork will also surpass beef. Again, hogs are rarely pastured. The earth has about 0.62 acres (0.25 hectares) of farmland per person, and about 0.30 acres (0.12 hectares) of grainland per person. As you do the math you realize that the earth does not have enough land for all inhabitants to enjoy an affluent diet. This land shortage will worsen in the future.

1.1.5 Soils profoundly affect human history. Farmers in Mesopotamia were irrigating 5500 years ago. Their fields were more productive then than they are now. Irrigated agriculture is rarely sustainable because it tends to raise water tables and increase soil salinity. In Egypt, where farming was successful and sustainable, civilization thrived. The plow was invented there some 6000 years ago. One observer theorized that the pyramids were built because of the large unemployed workforce--unemployed because agriculture was so successful that not all citizens had to be involved in food production. In China the Yellow River is known as China's Sorrow. It floods catastrophically on a regular basis. The Chinese built river dikes about 4000 years ago, and are still building them. The tremendous soil erosion upstream elevates the riverbed as suspended sediments settle out of the slow moving water. Artificial levees designed to prevent flooding only exacerbate the problem in the long run because the sediments are forced to remain in the river channel and raise the riverbed closer to the top of the levees. In North America modern settlers caused the erosion of about one-half of our original endowment of topsoil in only about 150 years of myopic farming.

1.1.6 The study of soils is a science of inherent value to mankind. Soil science includes two main divisions: edaphology and pedology. Edaphology is the study of soils as habitat for plants and other organisms. Xenophon, Cato, were early edaphologists. Van Helmont (1577 - 1644) performed a famous willow experiment, concluding that because the only thing he gave a growing willow was water, willows are made of water. He was partly correct but did not realize that the dry matter came mostly from invisible carbon dioxide in the air. Scientific advances accelerated in the 1700s and 1800s. Pedology is the study of soil as a geologic entity. Pedology was born in Russia in the late 1800s. The USDA systematic approach to pedology is based loosely on the Russian approach.

Students are encouraged to look up the following vocabulary words and to browse the following web sites.

作业

1. 解释下列词汇：

Edaphology; Pedology; Soil

Web sites

Worldwatch Institute Homepage. This organization provides environmental data and news to individuals and organizations interested in the environment. URL: www.worldwatch.org

Journal of Natural Resources and Life Sciences Education. This is an excellent electronic journal about natural resource education. Abstracts are free, articles are not. URL: www.agronomy.org/journals

1.2 Soil Components

What is this stuff we call soil? How do we systematically describe or compare soils? What are the components of soil? These questions and others are briefly answered in this lesson. Why briefly answered? The answers are brief because short answers to lots of questions at this point in your studies will allow you to put more detailed answers into context as those answers emerge later in the course.

1.2.1 One might ask, does soil spawn life? What is this material we call soil, that when found in the presence of sunlight and water it seems to generate living things. Do not get too hung up on semantics. Lots of people have written definitions of soil and you can write one too if you like. No one's definition is necessarily right or wrong. So, what asked does soil contain life-giving powers, the answer depends on whose definition of soil you choose. The USDA definition requires that soil contain living matter. An engineer's definition would be quite different. We encounter difficulties as we impose human systems over natural phenomena. When you view a forest, we humans would tend to say, "up there are the trees and down there is the soil," separating the plants from the soil. However, we normally consider the microorganisms living on the same soil to be an integral part of the soil. Again, learn concepts and facts but do not get too hung up on semantics.

1.2.2 Soils exist in and on the earth's crust. The crust tends to be about 3 to 20 miles deep. The crust is highly dynamic. Imagine the processes and forces at work resulting in the presence of a previous surface accumulation of sedimentary materials buried miles below the surface. The unconsolidated materials (that one would call soil) are sands, silts and clays.

1.2.3 Soil is three-dimensional. Consider how much water you could you add to a quart jar filled with dry soil. Probably about one pint, or half the quart volume of water could be added. Why? Because about half of a soil's volume is solids, the other half is pore space. The top surface of soil is what we normally see. Looking at the top of a soil, how might one tell a "good" soil from a "bad" soil? That answer leads to another question, "good" for what purpose? If one wants a good soil on which to raise horses, one might considered such soil surface features as slope, color, vegetation, texture, etc. The soil is more than the surface, it also has a vertical dimension. A vertical cross-section of soil is called a soil profile. Horizontal layers in the profile are called horizons. The uppermost horizon or topsoil is the "A" horizon, rich in organic material, with soluble material leached or washed out. This horizon is often about 1 foot deep. The next horizon typically is a subsoil horizon called the "B" horizon. Soluble and mobile materials wash into this horizon; it is often high in clay and salt. B horizons are often about 1 to 2 feet thick. A and B horizons collectively are called solum. Below the B horizon is material that is more or less unaffected by surface phenomena. This material is called parent material, or "C" horizon.

1.2.4 The pore space within a soil volume is air and water. The water is called the soil solution. This solution contains soluble salts, organic solutes, and some suspended colloids (solids that suspend in a fluid). The behavior of soil water is controlled to a great extend by pore size. Small pores have a great affinity for water and hold it very tightly. Larger pores allow water to escape easily, such as into a plant root or into the atmosphere by evaporation. Soil air has more CO_2 but less O_2 than the atmosphere. This is because of the time lag in diffusing gases into and out of the soil. Respiring organisms in the soil consume O_2 and produce CO_2. Because of this concentration gradient between the soil and the atmosphere, one can think in term of these soil gases constantly seeking, but never achieving, equilibrium with the atmosphere. For similar reasons, the soil air always has a relative humidity near 100%. Respiration releases water which evaporates much more slowly in the soil than on or above the soil.

1.2.5 The solids in soil are minerals and organic matter. Minerals can be either primary or secondary. The primary minerals on the earth cooled from a molten mass, and have not changed chemically since the day they came into existence. Secondary minerals form by precipitation or recrystallization of elements that were released by the weathering of primary minerals. Quartz and feldspar are primary minerals. The clays are secondary minerals. Rocks are mixtures of minerals. Igneous rock formed from molten magma. Sedimentary rocks are cemented accumulations of mineral materials. Common sedimentary rocks include limestones, sandstones, quartzite, and shale. Metamorphic rocks include slate (hardened shale) and marble (hardened limestone). The various rocks and minerals decompose and weather to form soil minerals. These soil minerals may be small versions of primary minerals (sand is usually small quartz rocks) or may be secondary minerals (as is the case with most clays). Soil minerals are mostly O, Si, and Al.

1.2.6 Organic matter includes living organisms and decomposing flora and fauna. Microorganisms include bacteria, fungi, algae and others. Living macro organisms are usually not considered part of the soil per se. Organic material can be actively decomposing, releasing nutrients. Within a year or so, organic materials such as crop residues stabilize and then the remaining residues decay very slowly. Stable organic material, very slowly decomposing, is called humus. Organic matter affects soil tilth, nutrition, and water relations. Decomposing organic matter provides plant nutrients. Stable organic matter does not, but increases the soil's ability to hold nutrients and water. An organic soil is dominated by organic matter, rather than minerals. Such soils are found in wetlands and in cool regions where production of organic materials exceeds rates of organic matter decomposition.

1.2.7 Soils is habitat for higher plants. Plants need support, O_2, water and nutrients, all of which come from the soil. Soils differ greatly in their ability to provide these necessities. Proportions of coarse material (sand) and fines (clays) influence availability of O_2 and water. Plants also need at least 13 mineral nutrients plus carbon and oxygen from CO_2 and hydrogen from water.

Students are encouraged to look up the following vocabulary words and to browse the following web sites.

作业：

1. 解释下列词汇：

Horizon; humus; biomass; igneous rock; metamorphic rock; sedimentary rock

2. Web sites

Soil Science Society of America Homepage. This is the professional society to which most

soils researchers and professors belong.
URL: www.soils.org

Digital video of soil microbiology.
URL: www.agron.iastate.edu/~loynachan/mov/

3. 阅读下面的文章

The Soils That We Classify

The word "soil," like many common words, has several meanings. In its traditional meaning, soil is the natural medium for the growth of land plants, whether or not it has discernible soil horizons. This meaning is still the common understanding of the word, and the greatest interest in soil is centered on this meaning. People consider soil important because it supports plants that supply food, fibers, drugs, and other wants of humans and because it filters water and recycles wastes. Soil covers the earth's surface as a continuum, except on bare rock, in areas of perpetual frost or deep water, or on the bare ice of glaciers. In this sense, soil has a thickness that is determined by the rooting depth of plants.

Soil in this text is 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 following: 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. This definition is expanded from the 1975 version of *Soil Taxonomy* to include soils in areas of Antarctica where pedogenesis occurs but where the climate is too harsh to support the higher plant forms.

The upper limit of soil is the boundary between soil and air, shallow water, live plants, or plant materials that have not begun to decompose. Areas are not considered to have soil if the surface is permanently covered by water too deep (typically more than 2.5 m) for the growth of rooted plants. The horizontal boundaries of soil are areas where the soil grades to deep water, barren areas, rock, or ice. In some places the separation between soil and nonsoil is so gradual that clear distinctions cannot be made.

The lower boundary that separates soil from the nonsoil underneath is most difficult to define. Soil consists of the horizons near the earth's surface that, in contrast to the underlying parent material, have been altered by the interactions of climate, relief, and living organisms over time. Commonly, soil grades at its lower boundary to hard rock or to earthy materials virtually devoid of animals, roots, or other marks of biological activity. The lowest depth of biological activity, however, is difficult to discern and is often gradual. For purposes of classification, the lower boundary of soil is arbitrarily set at 200 cm. In soils where either biological activity or current pedogenic processes extend to depths greater than 200 cm, the lower limit of the soil for classification purposes is still 200 cm. In some instances the more weakly cemented bedrocks (paralithic materials, defined later) have been described and used to differentiate soil series (series control section, defined later), even though the paralithic materials below a paralithic contact are not considered soil in the true sense. In areas where soil has thin cemented horizons that are impermeable to roots, the soil extends as deep as the deepest cemented horizon, but not below 200 cm. For certain management goals, layers deeper than the lower boundary of the soil that is classified (200 cm) must also be described if they affect the content and movement of water and air or other interpretative concerns.

In the humid tropics, earthy materials may extend to a depth of many meters with no obvious changes below the upper 1 or 2 m, except for an occasional stone line. In many wet soils, gleyed soil material may begin a few centimeters below the surface and, in some areas, continue down for several meters apparently unchanged with increasing depth. The latter condition can arise through the gradual filling of a wet basin in which the A horizon is gradually added to the surface and becomes gleyed beneath. Finally, the A horizon rests on a thick mass of gleyed material that may be relatively uniform. In both of these situations, there is no alternative but to set the lower limit of soil at the arbitrary limit of 200 cm.

Soil, as defined in this text, does not need to have discernible horizons, although the presence or absence of horizons and their nature are of extreme importance in soil classification. Plants can be grown under glass in pots filled with earthy materials, such as peat or sand, or even in water. Under proper conditions all these media are productive for plants, but they are nonsoil here in the sense that they cannot be classified in the same system that is used for the soils of a survey area, county, or even nation. Plants even grow on trees, but trees are regarded as nonsoil.

Soil has many properties that fluctuate with the seasons. It may be alternately cold and warm or dry and moist. Biological activity is slowed or stopped if the soil becomes too cold or too dry. The soil receives flushes of organic matter when leaves fall or grasses die. Soil is not static. The pH, soluble salts, amount of

organic matter and carbon-nitrogen ratio, numbers of microorganisms, soil fauna, temperature, and moisture all change with the seasons as well as with more extended periods of time. Soil must be viewed from both the short-term and long-term perspective.

Buried Soils

A buried soil is covered with a surface mantle of new soil material that either is 50 cm or more thick or is 30 to 50 cm thick and has a thickness that equals at least half the total thickness of the named diagnostic horizons that are preserved in the buried soil. A surface mantle of new material that does not have the required thickness for buried soils can be used to establish a phase of the mantled soil or even another soil series if the mantle affects the use of the soil. Any horizons or layers underlying a plaggen epipedon are considered to be buried.

A surface mantle of new material, as defined here, is largely unaltered, at least in the lower part. It may have a diagnostic surface horizon (epipedon) and/or a cambic horizon, but it has no other diagnostic subsurface horizons, all defined later. However, there remains a layer 7.5 cm or more thick that fails the requirements for all diagnostic horizons, as defined later, overlying a horizon sequence that can be clearly identified as the solum of a buried soil in at least half of each pedon. The recognition of a surface mantle should not be based only on studies of associated soils.

4. 试验一 AVAILABLE WATER CAPACITY

SCOPE

Available Water Capacity (AWC) is the amount of water available to plants from the time the soil stops draining water to the time the soil becomes too dry to prevent permanent wilting.This procedure determines the soil water content at Permanent Wilting Point (PWP) and Field Capacity (FC) and calculates AWC as the difference between PWP and FC.

PRINCIPLE

The water retentivity of a soil relates the amount of water retained in a soil to the energy state (potential) of that water. The water in the soil is equilibrated with imposed pressure to simulate the conditions for PWP and FC. The water content for each state is determined and AWC is calculated by subtracting PWP from FC.

SPECIAL APPARATUS

Pressure plate apparatus.

50 mL burette.

PROCEDURE

1. Place the sample-retainer rings on the porous plate. Using a teaspoon or small scoop, take a random, grab sample of soil <2 mm diameter, and dump the whole sample into the ring taking care to avoid particle size segregation. Level the soil. Carry out duplicate samples.
2. Add distilled water to the surface of the porous plate until it reaches halfway up the outside of the rings. Cover the plate and allow to stand overnight, adding more water as required to maintain the level.
3. When the soils are saturated, carefully transfer the plate to the pressure chamber and connect the outlet tube. Connect the outflow tube from the pressure chamber to the bottom of 50 mL burette. Apply the appropriate pressure. (See Table 1.)
4. When equilibrium has been reached (minimum 24 hrs) as shown by no change in volume in the draining burette, close the burette tap and release the pressure in the chamber.Transfer the

soil from each ring to a weighing tin and determine the moisture content according to the Soil Moisture Content (P1A/1).

5. Repeat the procedure for other required pressures.

Table 1. Comparison of pressure and pF

kPa	Bar	Atm	pF	Description
10	0.10	0.099	2.0	Field Capacity
20	0.20	0.197	2.31	
35	0.35	0.346	2.55	
60	0.60	0.592	2.79	
100	1.00	0.987	3.01	
200	2.00	1.974	3.31	
500	5.0	4.936	3.71	
1000	10.00	9.872	4.01	
1500	15.00	14.807	4.20	Permanent Wilting Point

CALCULATIONS

Moisture characteristic

Plot a graph of pF against moisture content (%).

Available soil water capacity

$$AWC(\%) = FC - PWP$$

Where:
FC = Field capacity (%)
PWP = Permanent wilting point (%)

REPORTING THE RESULTS

Report field capacity, permanent wilting point and available water content (%) (on an oven-dry basis) to one decimal place.

REFERENCES

Abbott, TS (ed) 1985, *Soil Testing Service: Methods and Interpretation*. NSW Department of Agriculture.

McIntyre, DS 1974, in Loveday, J (ed) *Methods of Analysis for Irrigated Soils.* Commonwealth Agricultural Bureaux Technical Commmunication No 54, Farnham Royal, England.

Chapter 2 Soil Formation

2.1 weathering

Why does one soil look different than another? What geological forces act upon soils and what are the effects of the action? The famous geologist, Hans Jenny, answered these and other questions in his description of five factors responsible for soil formation.

Rocks and minerals change by the processes of weathering. Typically weathering causes mineral materials to disintegrate into smaller parts. The elements released as products of weathering may form new, secondary minerals. Weathering products that are loose or unconsolidated are called soil. Weathering can be accomplished by one or a combination of physical and chemical processes.

2.1.1 Physical weathering

Physical weathering is most pronounced in cold and dry climates. Physical processes include effects of temperature. Most notable is the force exerted by the expansion of water as it freezes. Another physical process is abrasion caused by bombardment of minerals by materials suspended in wind and flowing water. Finally, plant roots established in the crack of rocks often exert a force strong enough to cleave the rock.

2.1.2 Chemical weathering

Chemical weathering dominates in warm or moist climates. Worldwide, chemical weathering processes tend to be more important in soil formation than physical forces. The processes include: oxidation and reduction (of great importance for iron-containing minerals), carbonation (dissolution of minerals in water that has been made acidic by carbon dioxide), hydrolysis (when water splits into hydrogen and hydroxide, and one or both components participate directly in the chemical process), and hydration (when water is incorporated into the crystal structure of a mineral, changing mineral properties). Minerals differ greatly in their resistance to weathering.

Soil Formation means the development of a particular soil in a particular place. Weathering produces unconsolidated mineral material that one would call soil. However the formation of any given unique soil includes processes that continue to operate long after this unconsolidated material is formed. The products of weathering are the materials in which soils form. Soil materials are often transported vertically within the soil profile. Materials can be added (such as humus from plants or sediments added by wind or water) or can be lost (such as by erosion or by leaching through the soil profile). The unconsolidated materials in which soils form is called parent material. The term, soil formation, implies the formation of soil horizons and other features in the parent material.

Parent material arrives on location through various routes and mechanisms. The parent material in a landscape may have been transported to the location. Residual soils formed in place from weathering of the underlying bedrock. Residual soils are common in the great plains of the United States. Residual landforms include mesas, plateaus and plains.

Stream deposits are very common worldwide. Such deposits are called alluvium or alluvial. Examples of alluvial soils are: flood plains (as along the Mississippi River), alluvial fans (as in the piedmont region of the southeastern states), lacustrine deposits (dispersed material deposited as a stream entered a lake), and marine deposits (flocculated or aggregated material deposited as a stream entered the sea). In some instances marine deposits form deltas.

Wind deposits are called eolian materials. Only small particles are readily carried by wind. Large sands are too heavy to be carried by most winds. Clays also rarely blow because they form aggregates with other clay particles producing large clods or peds. Silts and fine sands are examples of material readily carried by wind. Silts are small mineral fragments, barely visible to the naked eye. (A typical silt particle is about as wide as the thickness of a sheet of paper.) Wild-blown silt deposits are important in agriculture for the ease with which they are cultivated. Such deposits are called loess. Sand dunes and landscapes made of ash are also eolian.

Glaciers have profoundly affected the landscape of the northern states. These deposits from moving sheets of ice are called glacial materials or glacial till. During past 1.5 million years (Pleistocene--modern times) the world has experienced four ice ages. The most recent was the Wisconsin ice age, ending 12,000 years ago. Much of the soil in the midwest came from Canadian glaciers. Glaciers leave landforms such as: lateral moraines, terminal moraines, ground moraines, and outwash plains.

Gravity deposits are colluvial material or colluvium. Such material results from mass-wasting, mud flows, or the gradual movement of individual particles down a slope. These deposits are found on a relatively small-scale such as mountain valleys, and are usually coarse materials .

According to the classic work by Hans Jenny, five soil-forming factors account for the differences in soils. The five factors are: climate, relief, organisms, parent material, and time. The acronym "CROPT" may help you remember this.

Parent Material is the only factor that can be considered inherited as opposed to acquired. The effect of parent material on a soil include such feature as soil texture, pH and mineral constituents.

Climate is often considered the most powerful soil-forming factor. Climate is expressed as both temperature effects and rainfall effects. Temperature controls rates of chemical reactions. Many reactions proceed more quickly as temperature increases. Warm-region soils are therefore normally more developed or more mature than are cool-region soils. Rainfall affects leaching, pH and soil aeration. In addition to direct effects of climate, climate also profoundly affects vegetation which in turn also affects soil formation.

Organisms (biota) affect and are affected by soil formation. Man is perhaps now the most influential of all organisms. He affects the soil by such activities as: plowing, irrigating, mining, clearing, disposing and leveling. The effects of large animals other than man on the land are minor. The effects of vegetation on soil formation are very profound. Different soils form in a grassland than under a forest. Much of this difference is due to the rapid nutrient cycling in grasslands. Vegetation effects extent of cover, thereby influencing runoff and erosion. Vegetation type and amount directly influences the type and amount of organic matter accumulation on the soil, and thereby influences such soil chemical properties as pH and nutrient supply. Finally, vegetation is the food source for most microorganisms so the vegetation exerts a strong influence on soil microbial populations.

Relief (topography) modifies the effects of other factors. Relief modifies climate by affecting the smoothness of the surface and also the angle at which the soil surface orients towards the sun. A convoluted surface dilutes solar energy over more surface area than does a smooth surface. In the northern hemisphere a north-facing slope will be cooler than a south-facing slope. Relief also affects the amount of rainfall that infiltrates a given parcel of soil. A steep slope will encourage runoff. A soil in a sloping location will experience less effective rainfall than that which one would measure in a rain gauge. Likewise, a low area may receive run-on water beyond the actual rainfall. Also, relief influences erosion. Soil horizons form from the top downwards. If the topsoil readily erodes away as it forms, the soil formation processes appear to have halted.

Soil formation is a function of time. Soil development is a process, not an event. Soils change over time. Clays are secondary minerals. They form in the soil, then change forms, and all the while they are moving downward with leaching rainwater. Similarly, organic matter forms on the surface as it moves downward with rainwater. It declines after reaching a maximum as old soils loose their ability to produce vegetation fast enough to keep up with decomposition. These are highly dynamic processes. Soils as viewed today are just snapshots in time. Soils looked different in the past and will look different in the future.

作业：

1. 解释下列词汇：

Sand; silt; clay; pH; illuvial horizon; loess; landform; residual material; soil genesis; weathering.

2.2 Soil Morphology

2.2.1 symbols used in description of Soil Morphology

Morphology refers to form, shape, appearance or structure. As we study soil morphology we find ourselves at a loss for words--so we make some words up. This lecture is a parallel study of the form and structure of soils and the words and symbols used to describe those forms and structures.

Uppercase letters, O, A, E, B, C, and R are used to designate master horizons. The symbol "O" represents an organic horizon. Most soils have no O horizon, they are however, common in forests and swamps and other places where organic production exceeds decomposition. The symbol "A" means topsoil. Most soils have an A horizon, but it could have eroded off exposing a subsoil horizon. Some very young soils have not yet had time to form an A horizon. The symbol "B" means region of accumulation. Salts and clays accumulate below the A horizon in a B horizon. Most soils have a B horizon. The symbol "E" means eluvial or washed out. A small fraction of soils have an E horizon, usually between the A and B horizons. The symbol "C" means parent material, i.e., unconsolidated mineral material that has not been affected appreciably by weathering, leaching, etc. The symbol "R" means bedrock, i.e., mineral material that cannot be considered unconsolidated. It is too hard for roots to penetrate.

Various special cases exist. If two or more subhorizons exist within a master horizon, they can be designated by arabic numerals, such as B1 and B2, indicating a difference between two horizons within a B horizon. If a discontinuity occurs so that a master horizon is comprised of two or more distinct parent materials, this can be designated by preceding letters with Arabic numerals, such as 1B and 2B. Normally "1" before the first B is understood, and is omitted resulting a B horizon, followed by a 2B horizon. These special cases are not limited to B horizons.

Transition zones might have properties of two master horizons, and can be called AB, BA, BC, etc. Boundaries between horizons are often described. Boundaries separating horizons may be smooth, tongued, wavy, indistinct, or have other properties worthy of note.

Lower-case letters are used to describe the master horizons. Think of these descriptions as adjectives. For example, a plowed A horizon may be designated an "Ap" horizon, with "p" indicating that the soil has been plowed and is therefore not in a natural condition. As another example, a B horizon dominated by deposited clay is a "Bt" horizon. The "t" stands for the German word for clay. Many of these lower-case adjectives are used, a few of which are explained in the book . ***A typical soil in a semi-arid region may have a vertical sequence of horizons such as: Ap/Bt/Ck. In a cool forest the sequence may be: Oe/E/Bs/Cg. Many possible combinations of horizon sequences exist.

2.2.2. Diagnostic epipedons

Diagnostic epipedons are surface indicators of soil properties. Epipedon means topsoil, or surface horizon. Some epipedons are common and important to soil students. These are: mollic (a thick, dark, fertile topsoil, common in grasslands), ochric (a thin or light-colored topsoil, common in arid lands), umbric (an acidic, dark topsoil, common in the subtropics), and histic (an organic topsoil, not common but important for wetlands and other special cases).

Some specific kinds of subsoils are common and important. These are: argillic (a clay accumulation, very common in temperate zones), cambic (a weakly developed B horizon, often found in young soils), natric (a problematic clay accumulation with high sodium contents, common in the presence of a high water table), spodic (an acidic accumulation of humus or oxides, common in cool forests growing in sandy soil, usually found below an E horizon), calcic (an accumulation of $CaCO_3$, common in arid & semi-arid lands).

Soils can be degraded or destroyed. Degradation occurs through nutrient depletion as we break the nutrient cycle by harvesting crops and removing them from the field. Erosion of soil can be catastrophic as the topsoil blows or washes away, leaving only lower-quality B horizon as a plant growth medium. Humus levels can diminish due to decomposition if the soil is used to produce annual crops and is left bare much of the year. Many pollutants, including salt, can also degrade or destroy a soil.

Soil quality can be assessed. We frequently test soil to determine its suitability for agricultural, environmental or engineering purposes. Often these tests are on-going as part of a monitoring program. One can test: physical properties (texture, infiltration, aeration, temperature) chemical properties (organic matter, nutrients, pH, salinity, clay type), and biological properties (microbial biomass, mineralizable substrate).

Soils are mapped as unique individuals. The smallest individual that can be considered a unique soil is called a pedon. A pedon must be at least 1 m2 in area. The USDA uses explicit guidelines to differentiate soil units. They developed a system of Soil Taxonomy in the early 1970s. This system continues to evolve. The individual mapping units of soils are called soil series and phases of series. A series has a name like the "Victoria clay". A phase is a subdivision of a series, used only where necessary in soils mapping.

作业：

1. 解释下列词汇：

作业

Argillic；calcic；cambic；mollic；natric；ochric；umbric；pedon；series；soil horizon

2. 阅读下列文章：

Differentiae for Mineral Soils[1] and Organic Soils

Soil taxonomy differentiates between mineral soils and organic soils. To do this, first, it is necessary to distinguish mineral soil material from organic soil material. Second, it is necessary to define the minimum part of a soil that should be mineral if a soil is to be classified as a mineral soil and the minimum part that should be organic if the soil is to be classified as an organic soil. Nearly all soils contain more than traces of both mineral and organic components in some horizons, but most soils are dominantly one or the other. The horizons that are less than about 20 to 35 percent organic matter, by weight, have properties that are more nearly those of mineral than of organic soils. Even with this separation, the volume of organic matter at the upper limit exceeds that of the mineral material in the fineearth fraction.

Mineral Soil Material

Mineral soil material (less than 2.0 mm in diameter) *either*:

1. Is saturated with water for less than 30 days (cumulative) per year in normal years and contains less than 20 percent (by weight) organic carbon; *or*

2. Is saturated with water for 30 days or more cumulative in normal years (or is artificially drained) and, excluding live roots, has an organic carbon content (by weight) of:

a. Less than 18 percent if the mineral fraction contains 60 percent or more clay; *or*

b. Less than 12 percent if the mineral fraction contains no clay; *or*

c. Less than 12 + (clay percentage multiplied by 0.1) percent if the mineral fraction contains less than 60 percent clay.

Organic Soil Material

Soil material that contains more than the amounts of organic carbon described above for mineral soil material is considered organic soil material.

In the definition of mineral soil material above, material that has more organic carbon than in item 1 is intended to include what has been called litter or an O horizon. Material that has more organic carbon than in item 2 has been called peat or muck. Not all organic soil material accumulates in or under water. Leaf litter may rest on a lithic contact and support forest vegetation. The soil in this situation is organic only in the sense that the mineral fraction is appreciably less than half the weight and is only a small percentage of the volume of the soil.

Distinction Between Mineral Soils and Organic **Soils**

Most soils are dominantly mineral material, but many mineral soils have horizons of organic material. For simplicity in writing definitions of taxa, a distinction between what is meant by a mineral soil and an organic soil is useful. To apply the definitions of many taxa, one must first decide whether the soil is mineral or organic. An exception is the Andisols (defined later). These generally are considered to consist of mineral soils, but some may be organic if they meet other criteria for Andisols. Those that exceed the organic carbon limit defined for mineral soils have a colloidal fraction dominated by short-range-order minerals or aluminum-humus complexes. The mineral fraction in these soils is believed to give more control to the soil properties than the organic fraction. Therefore, the soils are included with the Andisols rather than the organic soils defined later as Histosols.

If a soil has both organic and mineral horizons, the relative thickness of the organic and mineral soil materials must be considered. At some point one must decide that the mineral horizons are more important. This point is arbitrary and depends on part on the nature of the materials. A thick layer of sphagnum as a very low bulk density and contains less organic matter than thinner layer of well-decomposed muck. It is much easier to measure the thickness of layers in the field than it is to determine tons of organic matter per hectare. The definition of a mineral soil, therefore, is based on the thickness of the horizons, or layers, but the limits of thickness must vary with the kinds of materials. The definition that follows is intended to classify as mineral soils those that have both thick mineral soil layers and no more organic material than the amount permitted in the histic epipedon, which is defined in chapter 3.

In the determination of whether a soil is organic or mineral, the thickness of horizons is measured from the surface of the soil whether that is the surface of a mineral or an organic horizon, unless the soil is buried as defined in chapter 1. Thus, any O horizon at the surface is considered an organic horizon if it meets the requirements of organic soil material as defined later, and its thickness is added to that of any other organic horizons to determine the total thickness of organic soil materials.

Definition of Mineral Soils

Mineral soils are soils that have *either* of the following:

1. Mineral soil materials that meet *one or more* of the following:

a. Overlie cindery, fragmental, or pumiceous materials and/or have voids[2] that are filled with 10 percent or less organic materials *and* directly below these materials have either a densic, lithic, or paralithic contact; *or*

b. When added with underlying cindery, fragmental, or pumiceous materials, total more than 10 cm between the soil surface and a depth of 50 cm; *or*

c. Constitute more than one-third of the total thickness of the soil to a densic, lithic, or paralithic contact or have a total thickness of more than 10 cm; *or*

d. If they are saturated with water for 30 days or more per year in normal years (or are artificially drained) and have organic materials with an upper boundary within

40 cm of the soil surface, have a total thickness of *either*:

(1) Less than 60 cm if three-fourths or more of their volume consists of moss fibers or if their bulk density, moist, is less than 0.1 g/cm^3; *or*

(2) Less than 40 cm if they consist either of sapric or hemic materials, or of fibric materials with less than threefourths (by volume) moss fibers and a bulk density, moist, of 0.1 g/cm^3 or more; *or*

2. More than 20 percent, by volume, mineral soil materials from the soil surface to a depth of 50 cm or to a glacic layer or a densic, lithic, or paralithic contact, whichever is shallowest; *and*

a. Permafrost within 100 cm of the soil surface; *or*

b. Gelic materials within 100 cm of the soil surface and permafrost within 200 cm of the soil surface.

Definition of Organic Soils

Organic soils have organic soil materials that:

1. Do not have andic soil properties in 60 percent or more of the thickness between the soil surface and either a depth of 60 cm or a densic, lithic, or paralithic contact or duripan if shallower; *and*

2. Meet *one or more* of the following:

a. Overlie cindery, fragmental, or pumiceous materials and/ or fill their interstices[2] *and* directly below these materials have a densic, lithic, or paralithic contact; *or*

b. When added with the underlying cindery, fragmental, or pumiceous materials, total 40 cm or more between the soil surface and a depth of 50 cm; *or*

c. Constitute two-thirds or more of the total thickness of the soil to a densic, lithic, or paralithic contact *and* have no mineral horizons or have mineral horizons with a total thickness of 10 cm or less; *or*

d. Are saturated with water for 30 days or more per year in normal years (or are artificially drained), have an upper boundary within 40 cm of the soil surface, and have a total thickness of *either*:

(1) 60 cm or more if three-fourths or more of their volume consists of moss fibers or if their bulk density, moist, is less than 0.1 g/cm^3; *or*

(2) 40 cm or more if they consist either of sapric or hemic materials, or of fibric materials with less than threefourths (by volume) moss fibers and a bulk density, moist, of 0.1 g/cm^3 or more; *or*

e. Are 80 percent or more, by volume, from the soil surface to a depth of 50 cm or to a glacic layer or a densic, lithic, or paralithic contact, whichever is shallowest.

It is a general rule that a soil is classified as an organic soil (Histosol) if more than half of the upper 80 cm (32 in) of the soil is organic or if organic soil material of any thickness rests on rock or on fragmental material having interstices filled with organic materials.

[2] Materials that meet the definition of cindery, fragmental, or pumiceous but have more than 10 percent, by volume, voids that are filled with organic soil materials are considered to be organic soil materials.

Chapter 3 Soil Physical Properties--Solid State

3.1 Particle related soil Physical Properties

The physical properties of soil are often the most important properties for evaluating the suitability of a soil for a particular purpose. Physical properties are properties one can describe with physical measurements such as length, mass, and temperature. Can the soil support trees, aquatic plants, desert shrubs? Or is the soil too cold, or too anaerobic, or too prone to drought. Can the soil withstand vehicle traffic, or will it fail under stress? A complete answer to these questions requires a thorough knowledge of the physical properties of the soil.

3.1.1 Physical properties are characteristics described by physical measurements. These often are the most important properties for determining the limitations and practical uses for a unit of land. These properties are texture, structure, bulk density and porosity. Aeration, color and temperature are also physical properties, and are discussed in the next lecture. Soil mechanics is an engineering field based on soil physics.

3.1.2 Texture refers to the relative proportions of sand, silt and clay. See Table 3-1 in the textbook to learn about what the USDA calls "soil separates". Basically, the part to remember is that sand is from 2.0 mm diameter to 0.05 mm. Silt is from 0.05 mm to 0.002 mm. Clay is mineral material smaller than 0.002 mm diameter. Organizations other than USDA use slightly different criteria. Sand is primarily quartz mineral, but can include feldspars and other small rock and mineral particles. Silts are also mostly quartz, and are often more angular than round. Clay-sized minerals are usually secondary clay minerals. Clay minerals do not have to be clay-sized according to the USDA soil separates criterion. Do not count organics or minerals > 2 mm diameter in determining soil particle sizes. The texture triangle is used to determine a texture class, based on soil separates. A texture class is the name of a region within the texture triangle, such as "silt loam". One can determine texture of a soil crudely by the feel of the soil, or more exactly by various lab techniques, such as sieving, or by measuring the rate at which suspendable particles fall through water. This is accomplished using Stokes Law, which says that the rate of fall through a fluid is a function of particle diameter.

3.1.3 Surface area is closely related to texture. Small particles have more surface per weight or per volume than do large particles. Break a pencil in two. Go ahead, do it. Now observe that the two broken pieces weigh the same and occupy the same volume as did the original whole pencil. However, the surface area has increased because the break is exposed. One could now break the pencil many more times, each time creating more surface area, but no more mass, weight, or volume. This illustrates the general rule that the smaller the particles, the more surface area per unit mass or per unit volume. In addition to this surface area affect, smaller particles arrange themselves in such a way that soil pores are smaller. Both surface and pore size phenomena are important because water adheres to mineral surfaces and has an affinity for small pores. Therefore clay (lots of surface, small pores) and sand (little surface area, large pores) differ markedly in water-holding properties. In common language, we call a clay soil a "heavy" soil because it is normally wetter than other soils. Soil texture affects plants in various ways, including water delivery, aeration, physical support, and fertility.

3.1.4 Structure is the arrangement of soil particles into aggregates. Peds are natural structural units; clods are artificial. Peds form by organic cementing agents, cation bridges, and in response to pressure from traffic or shrinking and swelling. Peds are described by their type (shape), class (size), and grade (strength or distinctness). The structure types are: platy (thin, horizontal), prismatic (long vertical faces), columnar (like prismatic but rounded tops), blocky (polyhedrals, angular or sub-angular), granular (small spheres or polyhedral units, with faces that are not casts of adjoining peds), and structureless (massive or single grain). Structure affects root penetration, infiltration, and aeration. The loss of organic matter or the presence of too much sodium cause structural deterioration and fewer pores.

3.1.5 Bulk density is the weight of a volume of bulk soil. Water is the standard by which other densities are compared. For water:
1 g/cc = 1 Mg/m^3 = 1 kg/L
Soil is about 50% pore space by volume, so this 50% of volume does not contribute to the weight of a dry soil, i.e., it dilutes the weight of solids over a larger bulk volume. Typical soil minerals have a particle density of 2.65 g/cc. Therefore a typical soil density is about half of particle density, or 1.3 g/cc but ranges from 0.9 to 1.8 g/cc. To determine bulk density, one determines the weight and volume of dry soil, as follows:

Can full of dry soil: diameter = 6 cm
height = 2.5 cm
volume = $p\ (^6/_2)^2\ (2.5) = 70.7\ cm^3$
weight = 99g
bulk density = $99\ g/70.7\ cm^3 = 1.4\ g/cm^3$
One might wish to know, how much does a field of soil weigh? From bulk density, one can answer this question:
1 hectare = $10{,}000\ m^2$
15 cm = 0.15 m
volume = $1500\ m^3$
if bulk density = $1.4\ g/cm^3 = 1.4\ Mg/m^3$
$(1500\ m^3)\ (1.4\ Mg/m^3) = 2100\ Mg = 2{,}100{,}000\ kg$
» 2 million kg/ha-15 cm
» 2 million lb/acre-6"
» 1000 tons/acre-6"

3.1.6 Porosity is a measure of pore space. Pore space influences how much water and air a soil can hold. On a volume basis:
% pore space + % solid space = 100%
% pore space = 100% - % solid space
but, % solid space = (bulk density/particle density) × 100%
or, (particle w/bulk volume)/(particle w/particle volume)
% pore space = porosity = 100% - (bulk density/particle density) × 100%

Pore size is also important as mentioned above, mainly because smaller pores have greater affinity for water than do larger pores.

作业

1. 解释下列词汇：
bulk density；particle density；ped；porosity；texture；clay；loam；sand；silt；soil separate

3.2 aeration and temperature

Two physical properties, aeration and temperature, exert a profound effect on soil life. Each soil-reliant organism has an optimal temperature and both high and low temperatures at which growth ceases. Likewise each macro-organism and most microorganisms need O_2 to complete their life cycle. Soil color can be a helpful indicator of aeration, mineralogy and humus content of a soil.

3.2.1 Natural respiration consumes O_2, and produces CO_2. Soil air is lower in O_2 and higher in CO_2 than the atmosphere. This is due to the difficulty with which gases in the soil exchange with gases in the atmosphere.

3.2.2 Dry atmospheric air has a fairly stable makeup. It contains (by mole fraction):

79% N_2； 21% O_2； 0.035% CO_2
Plus small amounts of other gases
These contents apply only to dry air, because water vapor (%RH) varies greatly, ranging from 20 to 100% relative humidity.

3.2.3 Rate of O_2 exchange and rate of O_2 consumption determine O_2 content in soil. Diffusion can be rapid or slow, but will most certainly be slower in the soil than in the atmosphere. Because wet soils have very little air-filled porosity, they can be anaerobic. Also, deep soils, clay soils, and heavily compacted soils are at risk for being anaerobic.

3.2.4 Anaerobic conditions affect soil biology and chemistry. As normal respiration ceases, anaerobic glycolysis proceeds. This is an inefficient and generally undesirable way to produce useable energy. Some microorganisms have the ability to reduce substances other than O_2, especially NO_3^-, SO_4^{2-}, and others. Anaerobic products are often toxic, and are generally unwanted.

3.2.5 Soil color reveals information about the soil. White specks are usually salts or lime. Dark colors usually indicate the accumulation of microscopic pieces of organic matter. Mottles indicate periods of poor aeration. Gray, colorless soils are usually anaerobic.

3.2.6 Color notation is defined by hue, value, and chroma. The Munsell color book is the standard from which colors are described. The hue is the rainbow color; red, yellow, etc. The chroma refers to purity of color, and is analogous to how much tint is put in a bucket of paint. The value is the relative blackness or whiteness, in other words, it describes what shade of gray the paint was before the tint was added.

3.2.7 Soil temperature affects soil biology and chemistry. Each organism has an optimum temperature for growth and reproduction. Some plants require heat units or chill units to complete their annual cycle. Temperature also affects chemical weathering--it proceeds more rapidly at higher temperatures. Temperature affects phase changes of water (evaporation and freezing).

3.2.8 Many factors affect soil temperature. The amount of heat absorbed is controlled by such factors as: reflection (at least 30% of solar radiation is reflected back into space), slope and aspect (a south-facing slope receives sunlight at higher intensity than does a north-facing slope), color and cover (affect reflection and wetness), specific heat (water has a much higher specific heat than does dry soil), photosynthesis (about 3% of solar energy is trapped by photosynthesis), and evaporation.

Most energy is used for evaporation. To evaporate 1 g water requires 540 cal at 20 °C. This is a very high number. Evaporation absorbs latent heat which can be released upon condensation.
Heat is transported by conduction and other mechanisms. Heat conduction is sinusoidal. Note that heat flow from soil surface to the subsoil undergoes a time lag and a damping effect.

Aeration and temperature are somewhat manageable. Management of temperature is accomplished by mulching (i.e., covering the soil with plastic, organics, etc.). Both aeration and temperature are affected by soil water management techniques such as irrigation and drainage.

作业

1. 解释下列词汇：

aeration；anaerobic；mulch；hue；value；chroma；specific heat；evaporation；respiration

3.3 *Soil Physical Properties—Mechanics*

Soil mechanics is a specialty within the field of civil engineering. Soil mechanics deals with soil response to physical stress. The stress may be weight of a building, vehicle traffic, or various other forces. Various classification systems have been devised to evaluate soil suitability for engineering purposes. Those systems are complex and will be only briefly described here.

3.3.1 Soil consistency refers to the soil's response to stress. Stress is pressure applied to the soil. In physics, pressure is force per area. The force applied to soil is normally weight. The response to stress is called strain. Engineers often plot strain as a function of stress to determine the point at which a material fails, called the yield point. Engineers are interested in both the deformability and firmness of a soil. A system called Atterberg Limits is used to describe the shrinkage limit, plastic limit, and liquid limit of a soil. As water is added to a dry soil, the soil changes from solid to semi-solid to plastic to liquid. The moisture content in the soil at the threshold between semi-solid and plastic is called the plastic limit. The moisture content in the soil at the threshold between plastic and liquid is called the liquid limit. Liquid limit is determined by forming a groove in a dish of soil and impacting the dish until the groove closes. The test is done using the apparatus in Figure 3-15 of the textbook, following the ASTM procedure D-4318. The plastic limit is determined by rolling a thread of soil on a glass plate until the 1/8-inch-diameter thread begins to crumble. This technique is also explained in ASTM procedure D-4318. A large liquid limit indicates high compressibility and high shrink swell tendencies. Subtracting the plastic limit from the liquid limit yields the plasticity index. A large plasticity index indicates low shear strength.

3.3.2 Soil mechanics classification systems. The two main systems in use are the AASHTO and the Unified systems . The Unified system is the older of the two. It is used by geotechnical engineers. Soils are classified based on their Atterberg Limits and on particle size as determined by sieving. The groups within the Unified system are explained in Figure 3-16 of the textbook. In general, the Unified system assumes that course material is better than fines, low liquid limit is better than high, a narrow range from the plastic limit to the liquid limit is better than a wide range, and that well graded material is better than poorly graded material. Well graded, means lots of sizes mixed together. This allows small materials to fill the pores between larger materials, and therefore gives a denser mix than does uniformly sized material.

The AASHTO system is newer and more widely used. It was developed by and for state highway departments. It also is based on Atterberg Limits and particle sizes. However it interprets these data differently than the Unified System. The AASHTO system is outlined in Table 3-12 of the textbook.

3.3.3 Soil compaction and consolidation. Soil compaction means the removal of air-filled porosity. Consolidation means the removal of water-filled porosity. For most engineering purposes, the more dense a soil is the better its load-bearing capacity. To make a soil more dense requires removing as much of the porosity as possible.

There exists for each soil an optimum moisture content for compaction, i.e., the moisture content at which a given pressure will create the most dense material. If the soil is drier than the optimum, too much friction exists between soil particles, so compaction is difficult. If the soil is wetter than the optimum, compaction may be easy but rather fruitless because most of the porosity is filled with water, not air. In general, removing water by compressing the soil is much more difficult than removing air, so the engineers aim is to compact, but not to consolidate, the soil. Compaction of soil at the construction site is accomplished through the use of rollers and vibrators.

Contractors and engineers often order a Proctor test (ASTM D-698) performed on the soil. The Proctor test determines the optimum water content for the compaction of that particular soil. The contractor then could dry the soil (or allow it to dry in the sun); or could moisten the soil. At the ideal moisture content the contractor's rollers will be most effective.

作业：

1. 解释下列词汇：

liquid limit；plastic limit；plasticity index；atterberg limits；consistency；compaction；consolidation；stress；strain

2. 阅读下列文章：

实验二

BULK DENSITY OF A SOIL CORE

Scope

This method covers the determination of the ratio of the mass to the bulk or macroscopic volume of soil particles plus pore spaces in a sample. A known volume of soil is sampled, airdried and weighed.

SPECIAL APPARATUS

A cylindrical steel core cutter approximately 75 mm long and 75 mm internal diameter with wall thickness approximately 3 mm, bevelled at one end to 15 mm. The cutter should be adequately lubricated to decrease friction and adhesion with grease or oil. (See Note.) If the lubricant is present in trace amounts only, it will not affect the physical measurement.

A steel dolly of diameter to suit the core cutter plus a 10 kg steel drop hammer, mallet or sledge hammer.

Drying oven at 105 ° C.

PROCEDURE

1. Expose approximately 300 mm square of the soil layer to be tested. Place the steel dolly on top of the cutter and hammer the latter into the soil layer until the top edge of the cutter is a few millimetres below the soil surface. Take care not to rock the core cutter. Repeat with other cores in close proximity so as to obtain sufficient replicates. Dig out the core samples, taking care not to damage them. Trim the ends of the core level with the ends of the cutter by means of a spatula and steel straight edge. Reject those that are not completely filled with soil. If the cores are satisfactory, pack them in loose soil in plastic bags or other containers. Two or three cores may be placed in one plastic bag but, in this case, wrap each core in aluminium foil. Transfer back to the laboratory in an insulated box packed with foam or vermiculite.

For subsurface samples, dig a pit of the necessary size and depth, and sample as above. If desired, samples may be taken from the wall of the pit.

2. Weigh the cutter containing the wet core to the nearest gram.
3. If the soil moves freely in the cutter, extrude the core into an aluminium tray and dry to constant weight at 105 ° C. Several days may be required. Removal of the core may be assisted by partial drying as a preliminary treatment. In cases where the core will not release from the cutter, the soil is dried in place for an extended period.
4. Weigh the dry soil with the cutter and then the cutter separately.
5. Calculate the internal volume of the core cutter, in cubic centimetres from its dimensions measured to the nearest 0.5 mm.

CALCULATIONS

Bulk Density

$$BD(Mg/m^3) = \frac{\text{mass of dry soil (g)}}{\text{Volume of core (cm}^3\text{)}}$$

Report Bulk Density in Mg/m^3 (equivalent to g/cm^3) on an oven-dry basis to the nearest 0.01 Mg/m^3.

Gravimetric Water Content

$$WCg(g/g) = \frac{\text{Mass of wet soil - Mass of dry soil}}{\text{Mass of dry soil}}$$

Report Gravimetric Water Content on oven-dry basis to the nearest 0.5 g/g.

REFERENCES

McIntyre, DS & Loveday, J 1974, Bulk density, in Loveday, J (ed) *Methods of Analysis for Irrigated Soils*. Commonwealth Agricultural Bureaux Technical Commmunication No 54, Farnham Royal, England.

Standards Association of Australia. *AS 1289E 3.3-1977. Determination of the field dry density*

of a soil: Core cutter method for fine-grained soils.

NOTE

Lubricate the sample tube inside and out by wiping it with a cloth containing a lubricant. A thin film only is required. Suitable lubricants are Shellmold 02 and P5, paraffin oil, vegetable oils and silicone oils.

Chapter 4 Water Chemistry

4.1 Properties of Water

After learning the rules of chemistry, the student learns to his or her dismay that water often seems to disobey these rules. In fact, the most abundant substance on the earth's surface has more anomalous properties than any other common substance. Strange as it is, materials and organisms on our planet behave the way they do because water behaves the way it does.

4.1.1 water is essential, scarce and plentiful. All earthly organisms need some water. Plants need water, usually in surprisingly large quantities. One single corn plant may use 1 liter of water per day; a large tree might use 200 or 300 liters per day. Water is known as the universal solvent, and is the solvent in the soil solution. To a great extent, soil water controls soil aeration and temperature. Water affects landscape erosion. Water on our planet is unevenly distributed. The wettest place on earth is a location on the big island of Hawaii, where it rains 460" per year. The wettest place in the 48 states is the Olympic peninsula of Washington, where it rains 140" per year. In general, the eastern states receive between 30 and 80" per year. The plains receive between 15 and 30" per year. Rainfall varies greatly among locations in the west. The state of Nevada averages less than 7" per year. About 84% of cloud water comes from oceans, but only 75% falls on oceans. Therefore, we have a hydrologic cycle, with surface water flowing from the continents to the oceans.

4.1.2 water is a unique substance. The water molecule would appear to be small enough to be a gas at room temperature, and yet it is a liquid. Indeed, most gases are considerably larger than water. Ice floats. This is a strange phenomenon among chemical substances. Usually the solid phase would be more dense than the liquid. If winter ice were to sink to the bottom of bodies of water, life on earth would be radically different. Water has a very high surface tension, and therefore tends to bead up. It also has a very high specific heat. Water has the highest heat of vaporization of all known substances.

4.1.3 Hydrogen bonding accounts for water's behavior. Because both of the hydrogens in a water molecule bond to the same side of the oxygen, water is polar $^{H}O^{H}$ with a + end on the hydrogen side and a - end on the oxygen side. Salts readily dissolve in this medium. Hydrogen bonding is a force between H and either N, O, or F. These three elements are the most electronegative. Because water is only H's and O's, the stage is set for the ultimate example of hydrogen bonding. In a pool of water, each H is covalently bonded to an oxygen, but retains a strong attraction (Hydrogen bond) for the nearest adjacent oxygen. In other words, each water is attracted to other waters. This phenomenon is called cohesion (the attraction of water to water). Soil minerals are also a source of oxygens to which water's hydrogens are attracted. Water, therefore, is strongly attracted to O-rich solids. This attraction of water to other materials is called adhesion. Adhesion and cohesion are best observed in the phenomenon of capillarity. You have probably observed water or an aqueous solution rising against gravity in a capillary tube, perhaps you have experienced this at the doctor's office as he or she pricks your finger, and then collects a sample of blood in a small glass tube. In capillarity, water rises until weight of column equals the attractive force between the water and the glass. For pure water the height of rise is approximately the following function of tube radius:

h » .15/r (in cm) or h » 15/r (in mm)

Soil and water attract for two reasons. First the soil is porous, and the pores behave much like capillaries. This is actually a minor consideration because natural drainage of water through a soil is strong enough to drain pores that are larger than 0.009 mm in diameter. The more important attraction is between water and solid surfaces. Surface films of water are always present in soil. The difference in water content between any two soils hinges on the question, how thick is the film?

4.1.4 The tendency of water to move or react or do work is determined by potential. The laws of thermodynamics tell us that spontaneous changes result in reduced potential energy states. Any given parcel of water has a particular potential energy. Potential is the work water can do relative to water at zero state. The zero state is pure water that is unattached to any surface and exists at the reference elevation in a gravitational field. Negative potential means work must be done to bring water up to the zero state. Usually, soil water has a negative potential. Suction or tension are terms used to refer to negative pressure. These terms are used to avoid negative numbers. A positive tension, means a negative pressure. Many other units are used to describe water potential. Hydraulic head is the unit used by engineers. Head units are in length, as the height of a water column. A pump, for example, might deliver 90 feet of hydraulic head. In science, as opposed to engineering, water potential is the preferred term. Water potential is expressed in energy units; but the question is, energy per what? If we express potential as energy per mass, typical units might be Joule/kg. Because it is more convenient, we often use energy per volume. This is convenient because energy per volume equals pressure, something we are familiar with. Typical pressure units in use are pascals, kilopascals, megapascals, and bars.

4.1.5 Water potential is the sum of four components. The first component is gravitational. This one is easy to visualize because we have lots of experience with gravity. The symbol used to depict gravitational potential is ψ_g, and the value can be + or — .

Pressure potential is also easy to visualize. Water will move from a high pressure environment to a low pressure environment. The symbol used to depict pressure potential is ψ_p. Ponded or flooded sites are pressurized for example. The pressure component in soil is either positive or zero.

Matric potential is the most important component in soil, but is more difficult to visualize. Water will not freely leave soil unless soil is very wet. This is because of adhesion and cohesion. Imagine placing a clump of dry soil on a table, then dropping a drop of water onto the clump of dry soil. If you elevate the soil off of the table, will the water leap out of it, dropping to the table? Of course not. It will stay in the soil, held my adhesion, or what we often call matric forces. The symbol for matric potential is ψ_m. These values are negative or zero, but never positive, because this water is not free to move to the zero state.

Often these three components are sufficient. For instance, to predict hydraulic flow, such as liquid flow through soil pores, one need consider no other component. However, in certain circumstances, another component is important. This other component is called solute potential. The tendency for water to undergo phase changes or to pass through membranes is controlled by the presence of solutes in the water. This is important in soil for two reasons: (1) evaporation of soil water is an important phase change, (2) water flow from soil into cells of organisms, including plant roots, requires transport through membranes. The symbol for solute potential is ψ_s. As with matric potential, solute potential is never positive; it can be negative for impure water, or approximately zero for very pure water. Solute potential is also called osmotic potential, because the process of passing selectively through a semi-permeable membrane is called osmosis.

4.1.6 Matric potential is the component of greatest concern. In wetlands, pressure and gravity are most important. But usually,

total potential (ψ_T) » matric potential (ψ_m)

A normal soil may have $\psi_m = -5$ bars. It actually ranges from nearly 0 to about -20 bars. For prospective, 5 bars of pressure is about equal to the pressure of 50 meters of water. In other words, a force equal to the weight of 50 meters of water would be required to remove water from a soil in which it was held with a matric potential of -5 bars. This magnitude of matric potential usually eclipses the small effect of the other components. The matric potential of a soil refers to the potential of the most easily removed molecule.

作业

1. 解释下列词汇：

matric potential; solute potential

4.2 Soil Water Measurement

Environmental monitoring has become an integral component of land management. Soil water properties are among the commonly monitored environmental characteristics. Specific reasons for monitoring soil water properties include optimizing benefits from irrigation, and protecting groundwater. This lecture discusses methods for monitoring soil water.

4.2.1 Water content. Water content can be measured in various ways. A few of the standard methods are briefly outlined below.

Gravimetric. This involves collecting a sample, weighing it, drying it, and then reweighing it. With these weights one can calculate θm.

Porous resistance blocks. These can be calibrated to measure either content or potential. Their performance is only acceptable in relatively dry soil where the $\theta \sim \psi$ relation is more or less linear. These are easy to use once calibrated, but are not particularly accurate.

Neutron probes. These provide high accuracy and non-destructive testing, by measuring water content surrounding an access tube installed in the soil. Because of the health risk and legal reporting requirements, their use is declining.

Time domain reflectometry. This relatively new method requires expensive instrumentation, but provides good accuracy.

Also, some minor methods in use include:

- frequency domain reflectometry
- capacitance probes

Lysimeters are often used for "balance-sheet" studies in which one monitors water in and water out of a system.

4.2.2 Water potential. Various instruments, a few of which are described below, can measure water potential.

Pressure plate. This is a lab apparatus used to determine water content for a wide range of matric potentials with reasonable accuracy. Tests are slow and laborious.

Tensiometer. This is an instrument for field use. These are commonly used in irrigation applications (see Figure 4-12 in the textbook). They only work on the wet end of the water release curve, and only measure matric potential.

Psychrometer. These provide the most scientifically rigorous readings, yet provide rather poor precision; however, precision improves drastically as soil wetness decreases. Measuring total water potential by psychrometer is possible because of the following physical chemistry relation:

$$\Psi_{total} = \frac{RT}{V} \ln RH$$

where R, T, and V are the ideal gas law constant, temperature, and volume; and RH is relative humidity.

As mentioned previously resistance blocks can be used to monitor water potential.

Piezometer. These are access tubes inserted in the soil. The tubes typically have a porous cup on the lower end to allow water in. They are useful for measuring pressure potential due to a water table.

Filter paper. Filter paper can be exposed to soil to measure the tendency for the paper to attract water from the soil. This is a low-tech method with accuracy similar to that of resistance blocks.

4.2.3 Water quality parameters. Water quality depends on the specific use intended. For plant growth, the factors of greatest concern are:

- salinity
- pH

specific ions likely to be toxic to plants: sodium, chloride, and boron.

These factors are of great importance in evaluating water quality for irrigation. The needs and tolerances of the specific plant to be irrigated would set the quality standards.

4.2.4 Hydraulic conductivity. Hydraulic conductivity is another name for the k value explained in the Lecture 10 discussion of Darcy's Law. This value is of great concern in monitoring the likelihood of run-off, the tendency of soil to become ponded or flooded, and the tendency of soil to protect groundwater from surface contamination. Many field methods of measuring hydraulic conductivity are in use. Two examples include measuring flow rates in concentric rings installed in the soil, and measuring the rate of flow into a shallow well dug into the soil surface. For simple evaluations of a soil for such purposes as a septic tank drain field, engineers often measure the rate of water level drop in an excavated cylindrical hole. This method is called the "Perc test". Laboratory tests are also used to obtain precise measurement of hydraulic conductivity, but normally give results that do not agree closely with field readings.

4.2.5 Evaporation studies. Ecosystem studies and agricultural applications often require knowledge of evaporation or evapotranspiration rates. This information can be obtained using lysimeters, Class A Evaporation Pans, or by using any one of various mathematical models. The Penman model and the Bowen Ratio model are examples. One can also measure indicators of plant stress. This is done by measuring canopy temperature with an infrared heat sensor, or by measuring leaf water potential with a psychrometer.

Students are encouraged to look up the following vocabulary words in the textbook glossary or elsewhere and to browse the following web site.

作业：

1. 解释下列词汇：

Lysimeter；Resistance Blocks；Tensiometer； Psychrometer；Hydraulic Conductivity

ain Entry: **ly·sim·e·ter**

2. 阅读下列文章

MOLLISOLS

10.1 Mollisols and the Mollic Epipedon

In defining Mollisols emphasis is placed on the presence of a mollic epipedon with a high base status. While the Mollisol order includes many dissimilar soils, extensive areas in the United States and other countries are Mollisols.

Although the mollic epipedon is required for all Mollisols it is also permitted in a number of other orders, including Inceptisols, Alfisols, Ultisols, and Vertisols. The mollic epipedon is not the only common feature of the Mollisols. The Mollisols must have, not only a mollic epipedon, but they must have a base saturation of more than 50 percent by NH40Ac in all subhorizons below the epipedon and within the control section. The mollic epipedon is required for Mollisols, permissible in four other orders, but prohibited in Entisols and Aridisols. The concept of the mollic epipedon is not only that of the dark-colored surface horizon of the Chernozem. Rather, it is the concept of a dark-colored epipedon in which there has been decomposition of plant residues underground in the presence of considerable amounts of calcium. In developing the concepts of the orders of *Soil Taxonomy*, we looked for some common feature that would group the soils of the former great soil groups of Prairie Soils or Brunizems, Chernozems, Chestnut soils, and Reddish Chestnut soils. These were soils that had formed under the influence of a predominantly grass vegetation. The only common features that we could find amongst these soils were, the presence of a dark-colored surface horizon of variable thickness and high base saturation. In the U.S., very commonly there was a horizon of accumulation of calcium carbonates, but this was not a universal feature because it was missing amongst the prairie soils or Brunizems.

We had in the previous classification, that had been in use in the U.S., a suborder titled, "Dark Colored Soils of the Semiarid, Subhumid and Humid Grasslands." This suborder was a modification of the classification of Marbut in which he divided all soils into the Pedalfers and Pedocals. In 1938 it was desired to group the prairie soils with the Chernozems on the basis of the dark-colored surface horizons and the grass vegetation. With this rather long traditional emphasis on the grouping of the grassland soils, it is not surprising that when we developed *Soil Taxonomy* we continued to give it an important place in the classification.

Nevertheless, we recognize that there were other dark-colored soils that have low base saturation and that it was always possible, in fact probable, that many of these had received an application of lime adequate to change their former umbric epipedon into a mollic epipedon. This is why the mollic epipedon is permitted in soils that normally have rather acid subsoil horizons. Having reached the decision to use the presence of the mollic epipedon and high base saturation at the definition of the order, we still had some other soils that did not have a grass vegetation but did have a mollic epipedon. Amongst these were the Rendzinas, and some brown Forest Soils. These had been considered amongst the others, as intrazonal soils, and there was no readily available order to put them in on the basis of their genesis alone. So we simply included them with the Mollisols as a separate suborder.

There are, of course, serious problems still remaining about the definition of the mollic epipedon. We have many soils that have formed under a swamp vegetation that have a mollic epipedon and that are currently grouped with the poorly drained soils that had formerly a grass and sedge vegetation. Therefore, the suborder of Aquolls has a much wider geographic distribution then do the Ustolls or the Udolls.

Setting the limits for thickness of the mollic epipedon created some difficulties. In a number of soils, the normal thickness of the mollic epipedon is just at the limit of 25 centimeters. This makes considerable trouble for a pedologist who is a purist and wants to classify everything on the basis of whether or not it fits the definition of a mollic epipedon without regard to whether or not the difference of one or two centimeters in thickness is relevant to the purposes of his soil surveys. We also have the problem of the soils with mollic epipedons in the intertropical regions. The definitions of *Soil Taxonomy* are written primarily for the soils of the U.S. and other temperate regions. We point out specifically that we have no good opportunity to test the classification of the soils in the intertropical regions in the U.S. and this testing must be done in other countries. We think, over time, that some of these problems can be worked out through the help of the international committees on taxonomic problems. **Question 5, Leamy**

10.2 Concepts and Criteria Used at Different Categorical Levels

In developing concepts and criteria used at different categorical levels, we have tried to keep together in *Taxonomy* soils that are similar enough that we can make some important statements about them. Consider the difference between the Albolls, where we use the albic horizon at the suborder level, and Albaquults, I think where we use it at the great group level. The Albolls are Mollisols that have an albic horizon. The drainage is always impeded to some extent, but they are a group of Mollisols with an albic horizon, and they cover the range from somewhat poorly to poorly drained. They did not want to separate them in the classification, according to the judgment of the field men about how wet they were. The horizons were easy to recognize; one could always, I think, have no problem in getting agreement about the presence or absence of an albic horizon, but great problems about getting agreement about the drainage class. So by separating the Albolls at the suborder level, and giving priority to the albic horizon over the aquic moisture regime, we kept this natural group of soils together in the taxonomy.

The distinction between the Aquults with the ochric epipedon and the albic horizon versus those with the umbric epipedon carry over into *Taxonomy* the old distinction between the Humic Gley and Low Humic Gley Soil of the southeastern states. They seem to think there that these were distinctions important enough to recognize at the great group level. We had used the moisture regime at the suborder level, so the first level at which we could bring in the differences in horizons was the great group level. Suppose we insisted that we use the albic horizon at the great group level, and all soils where it occurred. First, because it does not occur in all soils, we require an extra category to bring it in. Second, if we use it at the same categoric level in all soils where it does occur, then we split what seems to be a natural group of Albolls according to their natural drainage, which again does not always exist today, but is always restricted. These are soils that are naturally wet at some season, and the variability between the best and the worst drained members of the Albolls is not particularly significant so far as one can see.

10.3 Relationships in Soil Taxonomy to Zonal, Azonal, and Intrazonal Soils with Examples from Mollisols

The dominant process for the genesis of the Mollisols is considered to be the formation of the mollic epipedon as a result of underground decomposition of plant residues in the presence of appreciable calcium. This same process operates in some of the former intrazonal soils, but not the azonal ones. The intrazonal soils, the former Humic Gleys, have the same dominant process as do the Ustolls and the Udolls. The grouping of the Mollisols differs from Marbut's in that he separated the Udolls from the Ustolls in his highest category- -Pedalfers and Pedocals. In the 1938 classification it was decided that the Udolls with their dark-colored thick surface horizon belonged better with the Ustolls than they did with any other soils; so they were changed from intrazonal to zonal soils and were included with the suborder of dark-colored soils of subhumid and humid climates. This was a precedent in the '38 classification that carried over into *Soil Taxonomy* in developing the concept of the order of Mollisols. Marbut, for some reason, wanted to classify all soils on the basis of some property, so that he would have only two orders. We could see no reason to limit the number of orders to two, and it seemed best to try to segregate these dominant sets of processes. **Question 20, Cornell**

10.4 Classification of Eroded Mollisols

The soils that have lost their mollic epipedon through erosion create some questions about their classification. The philosophy of *Soil Taxonomy* is that a soil should be classified on its own properties, and not on those that are presumed to have existed at some time in the past, nor on the properties of adjacent soils. The use of the mollic epipedon to group the grassland soils of the great plains was unavoidable with the knowledge that we had of those soils at the time we developed *Soil Taxonomy.* We did state that we preferred to use subsurface horizons for the definitions of the higher categories because these would be the last horizons to be removed by erosion. There was, however, no criterion that we could find to retain the grouping that existed in the previous classification which called these soils dark-colored soils of the subhumid and humid grasslands. The possible alternative would be to find some characteristic that was common to Mollisols and was not found in other orders besides the mollic epipedons. I do not know what this might be. An alternative approach might be to recall that we are not classifying pedons, but we are classifying polypedons. The pedon is merely a sampling unit of the polypedon. The vast bulk of the eroded areas of Mollisols will have a mollic epipedon as well as pedons that do not have a mollic epipedon. in classifying these soils as Mollisols, when the mollic epipedon has been removed in places, perhaps most places even, it might be possible to write definitions such that when applied to a polypedon, the presence of these less eroded areas would be considered justification for putting the soil into the Mollisol order. This will require some study in the field, and there was no time to do this while *Soil Taxonomy* was being written. This question has been bothering the soil scientists of the midwestern states for many, many years, and we attempted at one time to get a study in Iowa of these soils with statistical controls, and somehow or other we never were able to find funds and personnel to do it. **Question 11, Witty & Guthrie**

In the development of criteria for the mollic epipedon there was no discussion about dropping the color requirements, providing the organic carbon content was at least 0.6 percent for the required thickness. I am quite aware of your problem of Mollisols that have lost most of their mollic epipedon. It is not unique to the U.S., this problem. It occurs in other parts of the World also. Here again, I tried to get some hard-core information about these eroded areas, what was actually present. I could never find out what the problem was, so I made no attempt to solve it without knowing what was there. I thought that, since we are classifying the polypedon and, in the eroded areas that I knew in Iowa, there would surely be a higher percentage of any particular polypedon that retained its mollic epipedon. I thought that potentially it would be possible to derive a definition that would keep the whole polypedon as a Mollisol even though it has eroded spots. But I could not get the hard information I needed and finally the time came I had to write the book. **Question 46, Minnesota**

In respect to eroded and uneroded Mollisols I suspect you will find very little difference in the percentage of organic carbon between them. One percent is an extraordinarily low limit for a Mollisol and we simply lack the data to develop a sliding scale for a relation between carbon and clay and silt in the mollic epipedons. The one percent limit was established for some soils from the western part of the Great Plains that were fine sands. In cultivation they get winnowed and a good bit of the clay and carbon are blown away but the color remains that of the Mollisol, the uneroded member of the series. The correlators on the Great Plains wanted to keep the series together and one percent was about the lowest level that we could get for the winnowed sand. **Question 73, Minnesota**

The relative number of pedons that are mollic within a polypedon of an eroded Mollisol needs further study. I would like to see some data on those to make up my mind about that point. I doubt that one point, one pedon would satisfy me, but I have a feeling you will find a great many if you take a look. This came up at Lubbock relative to some soils in Central America. They did have some numbers and it was something like 60 percent where the mollic epipedon remains and 40 percent where it was gone. In the case of your eroded Mollisols in Iowa, certainly if you have something like (60 percent) you should classify it as a Mollisol and allow these eroded areas to remain because their behavior is not greatly different from that of the uneroded Mollisols. It's very, very similar and it's a matter of a difference of a few centimeters, maybe 8, between the soil that is properly a Mollisol in Taxonomy and one that is not. It may be only 5 cm. However, eroded places might be and often are separated as segments of the polypedon according to the degree of erosion. This is acceptable philosophically, although I would reword some paragraphs in *Soil Taxonomy*. **Question 72, Minnesota**

10.5 Soil Moisture Regimes in Mollisols

Soil moisture regimes are related to the natural vegetation as well as to cropping practices. For example, in central Iowa in the Great Plains there are Mollisols with tall grass vegetation, mixed grasses in eastern Nebraska, and short grasses farther west. The precipitation gradually decreases from east to west. For establishing limits for moisture regimes, Newhall's model for predicting climatic data was used. I don't know of any other method that is being considered. The distinction between the Udolls and the Ustolls included the presence or absence of secondary lime. If the soil had secondary lime within certain depths, it was considered an Ustoll irrespective of the moisture regime. If (there was no secondary lime) it could, I think, be an udic subgroup of Ustolls or an Udoll depending probably on the moisture regime. This doesn't work, say, in South America and in Venezuela. The sediments in the Orinoco basin are dominantly non-calcareous, and it's only on calcareous sediments that you find any secondary lime in the Orinoco basin. In Argentina I have not studied the soils myself, but I am told there are some serious problems also between Udolls and Ustolls. They tell me there are petrocalcic Udolls in Argentina which certainly do not occur in the U.S. So, we have an international committee at the moment working on these moisture regime definitions, particularly with reference to inter-tropical areas. At the same time they can not separate them from the moisture regimes in more temperate climates. They must consider both, but the committee was set up because of serious problems in intertropical regimes. Any recommendations they make there are going to have an impact in temperate regions, so that a committee is going to debate the problems in the moisture regimes and will come up in a few years with some recommendations. What they will be, at this moment, I do not know. **Questions 54 and 56, Minnesota**

In the Udolls around Champaign/Urbana, and some other areas with Udolls, there is some secondary lime. But it's not soft powdery lime, it's hard lime concretions. They're excluded from the definitions.

In the inter-mountain areas the vegetation- moisture regime relationship is obscure. For example, for the Cryoborolls of the inter-mountain region, that if I collected all the series descriptions of the soils in a given family, some were under forest, some were under grass. Forest types might be one thing or another, Ponderosa pine or what-have-you. The vegetation and land use as described for the series varied appreciably from one series to another. I was not happy with what had been done, but I got no proposals for anything from anybody. I thought the best we could do was to start a study of morphology of some of these cryic soils in the west, but I found I had nobody to do it before I retired. Those of you who work with these soils should come up with some suggestion. **Question 58, Minnesota**

In addition to the Desert Project, I started a study on the High Plains for the reason that when I collected all of the descriptions and the data on the Paleustolls, not a one of them fitted the definition. I thought something must be wrong there. We should have had at least one sample of a pedon that fitted the definition of a Paleustoll, we had lots of series classified that way. It seemed logical to move from the desert to the margin of the desert on the High Plains because much of the information we got from the Desert Project was pertinent to the High Plains. **Question 58, Minnesota**

10.6 Proposal for the Classification of Soils Developed in Limnic Sediments with Low Organic Matter Content

The Venezuelan Soil Science Society has pointed out that there are deficiencies in *Soil Taxonomy* regarding the classification of soils developed in limnic sediments. Where limnic and organic soil materials are interlayered the soils are included in Histosols. But where the organic soil materials are lacking, a suborder of Limnents and a great group of Limnaquents are proposed. A limnic subgroup and families of marly and diatomaceous mineralogy are also proposed. Some of the soils involved are strongly calcareous, have a mollic epipedon, and are more appropriately classified as Rendolls rather than Ustolls. For these, Limnic Ustirendolls are proposed.

The situation of the soils formed in the limnic sediments with low organic matter content near Lake Valencia is not unique in the world, though, to the best of my knowledge the soils are not particularly extensive. I have seen somewhat similar soils in The Netherlands where the genesis may have been due to the cutting of the peat for fuel, but at any rate, the soil is composed of limnic sediments with too little organic matter to classify them with the Histosols. To remedy the situation the society should, therefore, submit their resolution to the Soil Conservation Service together with some documents about the nature of these soils. It is specified that the bulk density is low, but what is low? How low? There must be some measurements of the bulk density of the soil. I should also point out that you might, advisedly mention the presence of the cracks in the soil, even though the soils have been out of the bottom of the lake for an appreciable time. The original cracks which appeared at the former level are still present in at least some of the soils that I have been shown. The low bulk density is very apparent in the field, but it is not apparent to someone reading the documents of the Society, unless some numbers are included to document how low this bulk density is. **Question 32, Venezuela**

Chapter 5 Clay Minerals

5.1 Fine fraction of soil

Soils are made up of a complex mixture of solids, liquids and gases.

The solid fraction of soils are made up of organic and inorganic components. The inorganic component of the soil makes up more than 90% of the soil solids.

Inorganic components occur mainly in limited number of compounds with definite crystalline structure called minerals. The inorganic component includes both primary and secondary minerals.

The secondary minerals normally are found in the clay fraction of the soil which is the fraction of the soil solids which is less the 2 micron or 0.002 mm. Clay minerals are minerals which mainly occur in the clay sized fraction of the soil.

5.1.1 Importance of Clay Minerals. The clay minerals and soil organic matter are colloids. The most important property of colloids is their small size and large surface area. The total colloidal area of soil colloids may range from 10 m^2/g to more than 800 m^2/g depending the external and internal surfaces of the colloid.

Soil colloids also carry negative or positive charges on their external and internal surfaces. The presence of charge influences their ability to attract or repulse charge ions to or from surfaces.

Soils colloids play a very important role in the chemical reaction which take play in soil and influence the movement and retention of contaminants, metals, and nutrients in the soil.

5.1.2 Origin of Clay Minerals. Clay minerals are formed weathering a variety of minerals.The two main processes may involve slight physical and chemical alteration or decomposition and recrystallization.

Clay mineral types are normally determined by the types of minerals and acidity of the leaching water.

Based on their origins clays may classified as inherited, Modified, Transformed or Neoformed (see pages 147 and 148 of text for definitions).

5.1.3 Charge Development on Clays. Two main sources of charge in clay minerals are isomorphous substitution and pH-dependent charges.

Charge development of on silicate clays is mainly due to isomorphous substitution. This is the substitution of one element for another in ionic crystals without change of the structure. It takes place during crystallization and is not subject to change afterwards. It takes places only between ions differing by less than about 10 % to 15 % in crystal radii.. In tetrahedral coordination, Al^{3+} for Si^{4+} and in octahedral coordination Mg^{2+}, Fe^{2+}, Fe^{3+} for Al^{3+}. Charges developed as a result of isomorphous substitution are permanent and not pH-dependent.

In allophanes, some silicate clays e.g. kaolinite, and the metal oxides the main source of charge are termed pH -dependent charges because these charges depend on the pH of the soil. pH depend charges are variable and may either be positive or negative depending on the pH of the soil. In the metal oxides acid soils tend to develop positive charges because of the protonation of the bound on the oxide surfaces.

5.1.4 Type of Clay Minerals.

There are four major types of Clay minerals (see Table 5-1).

These include the layer silicates, the metal oxides and hydroxides and oxy-oxides, amorphous and allophanes, and crystalline chain silicates.

5.1.5 Silicate Clays.

The silicate clays are layers of tetrahedral and octahedral sheets.

The basic building blocks of tetetrahedral and octahedral sheets are the silica tetrahedron and the aluminum octahedra.

The Si^{4+} cation occurs in fourfold and tetrahedral coordination with oxygen whilst the Al^{3+} is generally found in sixfold or octahedral coordination.

Layer silicate minerals are sometimes defined on the basis of the number of certain positions occupied by cations. When two-thirds of the octahedral positions are occupied , the mineral is called dioctahedral; when all 3 positions are occupied it is called trioctahedral.

When one octahedral sheet is bonded to one tetrahedral sheet a 1:1 clay mineral results. Presence of surface and broken - edge OH groups gives the kaolinite clay particles their electronegativity and their capacity to absorb cations.

In 2:1 clay mineral an octhehedral sheet is bonded to two tetrahedral sheets. The octahedral sheet is generally sandwiched between the two tetrahedral sheets. The 2:1 clays can be classified into expanding (smectites) and non-expanding clays (Illite and micas) on the basis of the sheet where isomorphous susbstitution is taking predominantly taking place.

In the 2:1:1 lattice clays, a positively charge brucite sheet sandwiched between layers restricts swelling, decreases effective surface area, and decreases the effective CEC of mineral. The Idealized formular of half cell is $Al\ Mg_2(OH)_6)K\ (Mg3(Si4\text{-}x\ Alx)O_{10}(OH)_2$. Substitution occurs is in the tetrahedral layer and the layer change is variable but similar to mica. It occurs commonly in sedimentary rocks.

Table 5.1 Silicate Clay Mineral Groups:

Group	Layer Type	Layer Charge (x)	Type of Chemical Formula
Kaolinite	1:1	<0.01	$[Si_4]Al_4O_{10}(OH)_8.nH_2O$ (n= 0 or 4)
Illite	2:1	1.4-2.0	$M_x[Si_{6.8}Al_{1.2}]Al_3Fe.025Mg_{0.7}5O20(OH)_4$
Vermiculite	2:1	1.2-1.8	$M_x[Si_7Al]AlFe.05Mg0.5O_20(OH)_4$
Smectite	2:1	0.5-1.2	$M_x[Si_8]Al_{3.2}Fe_{0.2}Mg_{0.6}O_20(OH)_4$
Chlorite	2:1:1	Variable	$(Al(OH)_{2.55})4[Si_{6.8}Al0_{1.2}]Al_{3.4}Mg_{0.6}]20(OH)_4$

Adapted from Sposito1989. The Chemistry of Soils. Oxford University Press.

5.1.6 Sesquioxide Clays (Metal Oxides and Hydrous Oxides)

Also found in finer component. These tend to form in soils as Si is depleted by leaching.

Gibbsite is the most common Al oxide mineral and is often found in highly weathered soils such as oxisols in tropical areas and ultisols found predominantly in the southeastern U.S.

The most common iron oxides are Goetihte (FeO(OH) and Hematiite (Fe_2O_3) These are also found in highly weathered soils and gives many red soils their color.

The metal oxides gibbsite and goethite tend to persist in the environment because Si is readily leached than Al, or Fe and significant amount of soluble organic matter is present.

Manganese oxides are also quite common in soils. Apart from being an essential plant nutrient, they are an natural oxidant to certain metals such as As^{3+} and Cr^{3+}. Birnessite(MnO_2) is the most comon Mn oxide found in soils.

Most of the charges developed on the metal oxides are pH-dependent.

5.1.7 Allophanes and Imogolite

These are structurally disordered aluminosilicates.

They are normally derived from volcanic ash materials and constitute a major component of volacnic soils.

Allophane is often associated with clay minerals of the kaolinite group.

Imogolite has the empirical formula $SiAl_4O_{10}.5H_2O$.

5.1.8 Carbonate and Sulfate Minerals

The carboate and sulfate minerals are highly soluble compared to the alumino-silicates and are more prevalent in arid and semi arid regions.

The major carbonate minerals are calcite ($CaCO_3$) and Dolomite ($CaMg(CO_3)_2$.

The major sulfate mineral is gypsum.

5.1.9 Use of Clay Minerals.

Clay minerals have many industrial uses in the chemical and oil industries.

Organoclays, which have the metals in the clay replaced by large surfactant cations, such as long chain alkyl amine cations can be been used as liners in landfills to reduce transport of contaminants. Organoclays also could be used in wastewater treatment and spill control situations.

作业

1． 解释下列词汇：

Tetrahedra；Octahedra；Isomorphic substitution；Chlorite；Illite；Montmorillonite；Soil colloids；Vermicullite；Kaolinite；Sesquioxides；Allophane

5.2 Chemical properties of clay minerals

5.2.1 Ion Exchange in Soils:

As a result of negative charges developed by soil colloids ions are absorbed on the surfaces of these colloids in soils.

The ions absorbed are include Ca^{2+}, Mg^{2+}, K^{+}, Al^{3+}, and Na^{+}.

In humid regions Ca^{2+}, Al^{3+} and H^{+} are by far the most numerous cations absorbed.

Al^{3+} and H^{+} tend to dominate in humid regions.

In semi arid regions Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+} tend to dominate.

5.2.2 Sources. Negative Charge:

The main source of charge on clay minerals is isomorphous substitution which confers permanent charge on the surface of most layer silicates.

Ionization of hydroxyl groups on the surface of other soil colloids and organic matter can result in what is describes as pH dependent charges-mainly due to the dependent on the pH of the soil environment. Unlike permanent charges developed by isomorphous substitution, pH-dependent charges are variable and increase with increasing pH.

Presence of surface and broken - edge -OH groups gives the kaolinite clay particles their electronegativity and their capacity to absorb cations.

In most soils there is a combination of constant and variable charge.

5.2.3 Cation Exchange :

Displacement of one cation by another results in the process called cation exchange.

For example : H^{+} produced by organic acid.

Under high rainfall conditions, Ca leached reaction goes to right.

Under low rainfall conditions, Ca and other soils are not easily leached.

Reaction doses go to completion and tends to go to the left.

5.2.4 Factors Affecting Cation Exchange :

The charge of the ion. Generally ions with higher valency will exchange for those of lower valency. For example $Al^{3+} > Ca^{2+} > Mg^{2+} > K^{+}=NH_4^{+} > Na^{+}$.

For ions of same charge, the cation with the smallest hydrated radius is strongly absorbed because it moves close to the site of charge. For examples K with a hydrated radius of 0.532 nm, will exchange for Na , hydration radius of O.790 nm, on the exchange sites.

The rate of ion exchange in soils is affected by the type and quantity of organic and inorganic colloids. Clay minerals with 1:1 lattice tend to have more rapid rate of exchange than 2:1 clays which have both internal and external exchange sites.

5.2.5 Cation Exchange Capacity

The cation exchange capacity of soils (CEC) is defined as the sum of positive (+) charges of the adsorbed cations that a soil can adsorb at a specific pH.

Cation Exchange Capacity (CEC) is expressed as centimoles of positive charge per kilogram (cmol kg^{-1}) , of oven dry soil..

Earlier unit was meq per 100 g soils.

Equivalent weight : Quantity that is chemically equal to 1 gram of H.

Number of H in equivalent weight is 6.02 x 1023 or Avoagardo's number.

Milliequivalent is equal to 0.001gm of H.

Example 6.02 X 1020 charges.

Total cation exchange capacity of the soil is the total number of exchange sites of both the organic and mineral colloids.

5.2.6 Estimating CEC and Exchangeable Cations. (Refer to in text)

Table 5.1 Cation Exchange Capacities of Clay Minerals

Colloid Type	CEC (cmol Kg^{-1})
Kaolinite	2-15
Montmorillonite	80-150
Chlorite	10-40
Vermiculite (Trioctahedral)	100-200
Vermiculite (Dioctahedral)	10-150
Allophane	3-250
Gibbsite	4
Goethite	4

Adapted From Sparks 1995. Envornmental Chemistry of Soils. Academic Press.

5.2.7. Cation Exchange Capacities of Soils

The CEC of a given soil is determined by the relative amounts of different colloids in that soil and by the CEC of each of these colloids.

Sandy soils generally have lower CEC than clay soil because coarse textured soils have lower amounts of both clays and organic matter.

Table 5.2

Soils Order	CECs (cmol kg^{-1})	pH
Ultisols	3.5	5.6
Alfisols	9.0	6.0
Spodosols	9.3	4.93
Mollisols	18.7	6.51
Vertisols	35.6	6.72
Aridisols	15.2	7.26
Inceptisols	14.6	6.08
Entisols	11.6	7.32
Histosols	128.0	5.50

Adapted From Holmgren et. al. (1993). J. Environ. Qual. 22:335-348

5.2.8 Importance of Cation Exchange

Cation exchange at negative sites is major retention mechanism for heavy metals, e.g. Cd, Pb and Zn.

5.2.9. Measurement of CEC

The CEC of soil is usually measured by saturating the soil with an index cation such as Na^+, removal of the excess salts of the index cation with a dilute solution, and then displacing the Na^+ with another cation .

The amount of Na^+ displaced is then measured and the CEC is calculated.

5.2.10. Anion Exchange and Adsorption

Anion exchange arise from the protonation of hydroxyl groups on the edges of silicate clays and on the surfaces of metal oxide clays.

Anion exchange is inversely related with pH is greatest in soils dominated by the sesquioxides.

The anions Cl^-, NO_3^-, and SeO_4^{2-} and to some extent HS^- ands SO_4^{2-}, HCO_3^-, and CO_3^- adsorb mainly by ion exchange.

Borate, phospahate and carboxylate adsorb principally by specific adsorption mechanisms.

5.2.11. Metal Cation Adsorption

The ralative affinity of a soil adsorbent to for a a free metal cation with a given valence is positively correlated with the ionic radius.

$Cs^+ > Rb^+ > K^+ > Na^+ > Li^+$

$Ba^{2+} > Sr^+ > Ca^{2+} > Mg^{2+}$

$Hg^{2+} > Cd^{2+} > Zn^{2+}$

For transition metals the relative adsortion affinities does not conform strictly to ionic radius and tend to follow the following order:

$Cu^{2+} > Ni^{2+} > CO^{2+}\ Fe^{2+} > Mn^{2+}$

作业：

1. 解释下列词汇：

Cation Exchange Capacity；cation exchange；anion exchange；percent base saturation

2. 阅读下列文章：10.7 Mollisols with Relatively Low CEC

Oxic subgroups of Argiudolls and Haplustolls are based entirely or in part on a CEC of less than 24 meg per 100 g clay by NH40Ac. The Mollisols of the U.S. and Europe mainly are on late Pleistocene or even Holocene surfaces. Minerals are not weathered to the extent they are in some parts of the tropics. Do the Mollisols have mostly 2:1 lattice clays? It is suggested that the International Committee on Soils with Low-Activity Clays and on Oxisols should consider the classification of these relatively low CEC Mollisols.

The only good examples of oxic subgroups of Mollisols, that I know of, comes from the assembled data on the soils of the former Belgian Congo or Zaire, where we have soils that have properties of Mollisols as they are defined in Taxonomy, but that have kaolinitic clays and free oxides for the argillic horizon. These are intertropical soils, I think not necessarily from weathered sediments, but possibly from preweathered sediments. Under the high temperatures and the high rainfalls there, the surprising thing is that one finds Mollisols. Their presence may be due to the vegetation which would mostly be calcium- collecting evergreen forest trees.

I don't know the species or their classification. I have never visited these areas. I think that the collected data from INIAP or INEAC on the soils of Zaire probably will list the botanic names of the native vegetation that was growing when they sampled the soil. The botanic classification is useless to tell me whether it is a tree, grass, shrub, legume, or a non-legume or what have you. I only know it is a plant because the book says so, it is the vegetation. **Question 123, Texas**

10.8 Mollisols in Intertropical Regions

In the key to orders of *Soil Taxonomy* item G.4.C was designed to exclude some soils with a mollic epipedon and an isomesic or warmer isotemperature regime from Mollisols. The problem was recognized in Puerto Rico, in particular, where we had a Vertisol at the base of a slope which may or may not have a mollic epipedon. The soils were developed from basic rocks and became thinner as we moved up the slope. The soils were clayey with montmorillonitic mineralogy, but they were not Vertisols because the bedrock was too shallow. Going further up the slope we came into rather shallow lithic subgroups of Inceptisols. As we went from the very shallow Inceptisols at the top of the slope to the Vertisols at the base, we had a lot of vertic subgroups that had a mollic epipedon. We wanted to permit these vertic subgroups to be with or without a mollic epipedon. They were all marginal, one way or the other, but we didn't want to force a split in the series as we intergraded from Inceptisols on the upper slopes to the Vertisols on the lower slopes. We wanted to keep that range of soils together in one series. This was the basis for this particular requirement. What we have done there is to define the vertic subgroups. These things could be greatly simplified if they didn't have, here and there, some soils that straddle one of the limits of a diagnostic horizon, and desiring to keep them as a natural unit we had to permit the presence or absence of the mollic epipedon in the Inceptisols. So you will find something parallel to that in the full definition of the Inceptisols. You won't find it in the key because we have already taken care of it under the Mollisols. The Inceptisols are just, "other soils that". It takes all of this verbiage here for just a few hectares of soil, practically. **Question 77, Texas**

10.9 Skeletans in Argillic Horizons and Incipient A2 (E) Horizons

In the stable uplands of Iowa the loess-derived soils may have developed, at times at least, under woodland vegetation succeeded by grasses. In Illinois we discussed the difference between the Tama in one part of Illinois versus another. We have the same differences in Iowa. in some of the Tama, the argillic horizons show very distinct skeletans and, in other kinds of Tama in other areas, do not. We began to discuss this at least in 1930 in Illinois. The work of Ruhe and Walker on the vegetative sequence in Iowa would suggest that at least some of the Tama at one time had a forest vegetation, and these skeletans in the argillic horizons, may date from that time. This was a boreal forest and the skeletans are much more distinct in the Boralfs now than in the Udalfs. So far as I can see, there is this genetic difference within the Tama series in both Illinois and Iowa. We never could make any different interpretations for one kind of Tama than we made for the other and while we have discussed both in Illinois and Iowa about the wisdom of making the separation; nobody has ever seriously proposed that they separate them in mapping. **Question 166, Minnesota**

In an earlier publication, *Prairie Soils of the Upper Mississippi Valley,* the thinking at that time did not consider as Prairie Soils, soils having a lighter-colored eluvial horizon above the argillic horizon, even though the plow layer of the soil was six or seven inches thick and was dark in color. In that paper we were considering the various soils that had been called Prairie Soils, but we knew nothing about those in the western states or on the southern plains. So we specifically titled the paper to eliminate those Prairie Soils from the discussion. Our thinking, at that time, was that those were Gray-Brown Podzolic soils and could be distinguished from the Prairie Soils by the presence of what we then called an A2 horizon. And those, I think, have remained as Alfisols, not as Mollisols. **Question 160, Minnesota**

While there are some soils with a so-called incipient or more recognizable A2 horizon with platy structure; these are disregarded in *Soil Taxonomy.* If the colors, dry and moist, are dark enough for a mollic epipedon, the distinction of the platy structure was not brought into *Taxonomy. I* had long discussions in Iowa about whether or not, say in the loess in northeastern Iowa, we could identify three or four series: the one without any forest influence, the one without any grass influence showing in the profile, then a prairie soil intergrading to a forest soil and the forest soil intergrading to the prairie soil. And the general feeling in Iowa was that we could only recognize one intergrade, not two. And having had those long discussions when we got into the business of writing *Soil Taxonomy,* we did not provide for both intergrades, only for one, the forest soil that still shows a prairie influence. **Question 161, Minnesota**

10.10 Sloping Families of Aquolls, Other Great Groups and Histosols

There are sloping families provided for in Aquolls and Aquults. These are often wet soils; they must be drained for cultivation, and the common practice is to shape these nonsloping soils to provide surface drainage. The sloping members do not require shaping for drainage, although they require some sort of interception tile to cut off the seepage water. The same thing would be true for a good many of the Histosols. If these are cultivated and the polypedon is flat, then normally you have the soil ridged very steeply to provide for a better aerated medium for plant growth. We have other Histosols that are naturally sloping with slopes (in Malaysia) up to 50 percent or more. To get at the series one has to consider the polypedon shape rather than the slope of the individual pedon. Question 33, Cornell

10.11 Methods of Determining Base Saturation

There were two reasons why the base saturation for some soils is based on the sum of cations and for others on ammonium acetate extractable cations. One reason we didn't fully understand at the time, but we knew that the difference existed. One was that we had regionalized our laboratories, and in the eastern part of the U.S., where we had most of our Alfisols, the laboratory used the sum of cations to measure the base exchange capacity and base saturation. On the Great Plains where we had a lot of calcareous soils so the laboratory at Lincoln used ammonium acetate extraction, because the sum of cations doesn't work in the calcareous soils. Most of our data on the Mollisols were accumulated at the Lincoln lab where pH was measured and base saturation was measured by ammonium acetate at pH 7. Most of our data on Ultisols were from the Beltsville laboratory where these same measurements were made by the sum of cations. When we began to look at 35 percent or 50 percent or what have you, as a limit that would affect the classification of the series, we could not very well compare the two methods because we had only the sum of cations on the Ultisols and only ammonium acetate on the Mollisols and the Inceptisols. We had a few soils of which we had both. And one of those was the pedon I used in the *Seventh Approximation* as an example of an Ultisol. Now it just happened that that was quite rich in free oxides as well as kaolinite. It had a very considerable pH-dependent charge. So that it went as an Ultisol, if we used sum of cations, and it went as an Alfisol if we used ammonium acetate. Some of the best Ultisols were Red–Yellow Podzolic soils in the southeast at that moment. So without realizing what caused that pH-dependent charge at that moment, we went ahead and said, well, this soil, a representative. Red-Yellow Podzolic soil, is an Ultisol if we use sum of cations and 50 percent by ammonium acetate but where you have a large pH-dependent charge that breaks down and it just happens that that particular soil was one that had a large pH-dependent charge. That's how it happened. **Question 149, Minnesota**

The second reason was we had no data for the Mollisols on base saturation by the sum of cations because in calcareous soils it is impossible or was impossible to determine the base saturation. We could assume the calcareous soil was saturated, but we could not assume what the exchange capacity really was. This was the only method by which we had any data, and so we had to define the method by the availability of the data. In most soils with a low pH–dependent charge, the 50 percent base saturation is equivalent to 35 percent by sum of cations, but if there is a high pH-dependent charge, this relationship breaks down. **Question 76, Cornell**

10.12 Aquic Subgroups

In the definitions of aquic subgroups, depths to 2 chroma mottles are within one meter for Aquic Argiustolls, 75 cm for Aquic Haplustalfs, and 75 cm and the upper 12.5 cm for Aquic Haplustults. I cannot tell you why these different depths were selected because these subgroup definitions were developed in work-planning conferences that I could not always attend. If I did attend one I could only sit in the discussions of one committee. I simply do not know the answer. If it seems irrational and irrelevant to interpretations then changes should be proposed. I think that we must not tie our hands by trying to be completely consistent at this moment. Our only consistence is that we want to get the taxa about which we can make the most important statements and the greatest number of them.

I should point out that when you are dealing with Udalfs and/or Udults the shallow water table can be an impediment to use. When you are dealing with Ustalfs and Ustolls the shallow ground water may be a benefit. In northwestern Iowa where we have a relatively thin mantle of loess over a fine-textured till, the ground-water perches above the till. Crop yields are better because of it, because the soils then retain and can supply more water. These are considered Udolls at the moment but they are getting marginal to the Ustalfs, and I don't have much personal experience with the Ustalfs. **Question 137, Texas**

10.13 Cumulic, Fluventic, and Pachic Subgroups

There are implied differences in locations in the landscape in which soils in cumulic, fluventic, and pachic subgroups occur. Cumulic soils receive fresh sediments at a rate sufficiently slow for organic matter to build up and the mollic or umbric epipedons are thicker than those of the typic subgroup. The carbon content of the soil varies irregularly with depth, or the content is higher than is present in typic soils at stipulated depths (usually 1.25 m), or both. Many of these soils are at the bases of concave slopes where sediments accumulate slowly. But the landscape is not stable long enough for argillic horizons to form. Cumulic subgroups are provided in Mollisols and Umbrepts.

Fluventic subgroups are in less stable areas in which sedimentation is sufficiently rapid that the thickness of the epipedon does not exceed the limits of the typic soils. The organic carbon content of the soil decreases irregularly with depth or it is higher at a stipulated depth than allowed in the typic subgroup, or both. Fluventic subgroups are provided for some Inceptisols and Mollisols. Fluventic and cumulic subgroups were not recognized in the Andepts because it was assumed that these soils would have repeated additions of volcanic ash or pumice. Buried Al horizons were considered normal in Andepts rather than abnormal.

Pachic soils are in more stable positions in the landscape than cumulic or fluventic soils, but for some, the reason for the pachic soils is not always apparent. Pachic is used with Mollisols both with and without argillic horizons and with Umbrepts. The thought was at one time this over-thickened epipedon (thicker than normal for the soil environment) may reflect some local variation in moisture availability.

We have, in the Ustolls, some soils that have a much thicker mollic epipedon than their neighbors. As the Ustolls get drier we normally expect the mollic epipedon to thin, but in the regions where normally the mollic epipedon is thin, there are Ustolls with a rather thick mollic epipedon. The reasons for this, at the time we were working on Taxonomy, were unknown. As far as I know, they are still unknown. The correlation staff felt that these should be separated from the soils with the thinner mollic epipedons. Soils with thickened mollic epipedons were recognized at the series level, and the correlation staff wanted to carry this to a higher categorical level, so the pachic subgroup was introduced. I'm told, at Lubbock, that these pachic soils are more productive than the others, although they receive, so far as anyone knows, the same precipitation. Precipitation is one of the controlling factors on productivity in the Ustolls.

In the Udolls we don't have this variability in thickness of the mollic epipedon within the U.S., except where it is presumably the result of erosion, post-cultural erosion. In some Udolls of the world, we now have to think a little bit about Borolls instead of Udolls. There are Udolls in Ecuador with a two meter mollic epipedon that runs from sideslope across the ridge and down the other side so it is not due to accumulation of materials as a result of erosion, natural or cultural. Soils recognized in pachic subgroups are principally in ustic or xeric moisture regimes except some Umbrepts and Borolls which have a udic moisture regime. **Question 50, Minnesota**

10.14 Composition of Organic Matter

The Russians use the ratio between humic and fulvic acid in organic matter as diagnostic criteria. We don't have a lot of data in the U.S. on this subject. You have to go to other countries. For example, I have to go to Canada for a moment, where they took a soil, I think it was in Saskatchewan, and with fertilization over a period of a couple of decades, the ratio reversed itself. I believe it's a very unstable thing in the soil. That was the reason, after having looked at what data I could find, I found this reversal of the ratios as a result of cultivation using reasonable fertilization in contrast to the soil under the natural vegetation. It may be that it has a good deal of genetic significance in uncultivated soils. But if we're going to keep the cultivated and the uncultivated equivalents together, it's a difficult thing to use. ORSTOM, the French overseas soils people, commonly make that analysis. They find, between the Mollisols developed in ash and the Andepts, there's a very large difference. Some of the Mollisols in ash have almost a hundred percent humic acid and there's virtually none in the Andepts of Ecuador.

This certainly reflects something that has been going on in those soils. The Mollisols are cultivated in Ecuador and have been for some hundreds of years, and the Andepts mostly are left alone and grazed. But there's an enormous difference in this ratio there. You find this in publications of *Pedologie* and in ORSTOM's *Cahier de Pedologie.* **Question 153, Minnesota**

In cultivated soils humic acid, rather than fulvic acid, predominates.

I've never seen such Mollisols as they have in the ash in Ecuador where the clay is pure halloysite. Those soils have been cultivated by the Incas for an unknown length of time, but without fertilization. I talked with one cultivator who was about to harvest his corn, and I estimated that his yield would be about 40 bu/ac. I asked him what fertilizer he used, and he said he had never used any. It strengthened my desire to keep the Mollisols together.

Yes, (at one time in the development of the mollic epipedon concept we had the notion of using the carbon-nitrogen ratio as a part of the definition, but it was abandoned). As a general rule, the C/N ratio in the Mollisols will be 12, 11, 10, something in that range, but we kept finding the exceptions for reasons that are unknown to me, where the C/N ratio went up to 15 or 16, particularly in the Aquolls. And so we thought if we had to go that high it wouldn't make any particular distinction from other kinds of soil, and we dropped that ratio. As I recall, the very wide ones were always in an Aquoll. **Question 155, Minnesota**

10.15 Hard and Massive Surface Soils

The restriction against a hard or very hard consistence and the massive structure in a mollic epipedon was introduced to keep out of Mollisols certain soils that have a xeric moisture regime in southern California. These soils have what the Australians call a "hard - setting" A horizon such that, if one wants to sample a soil in the summer, he starts with an air-drill such as they use to break concrete pavement. Once you're through the epipedon, digging by shovel is possible. These soils have a color and a carbon content that is just marginally adequate for a mollic epipedon and we wanted to keep them fairly out of the Mollisols and keep them together whether or not there was just a little more carbon or a little less or whether the color value was closer to three than four but lay between. The Mollisols that we know in the U.S. do not present these same problems with sampling or plowing. They are structured enough that they may be plowed when dry, whereas, the ones we wanted to keep out are very difficult. The British groundnut scheme failed because of the nature of the epipedon. They tried to work the soils with big tractors and heavy plows but the plows were destroyed as they would be trying to plow up a concrete pavement. It is the hard and very hard dry consistence of the massive hard–setting epipedons that we want to keep out of the Mollisols.

In South Australia the soil with a hard, massive epipedon is comparable to the cultivated Xeralfs in the U.S. They may disappear over a distance of only three or four miles. We went into more arid climates and there we found soils with argillic horizons, they had a very soft epipedon. The restriction seemed to work on the basis of the soils that they showed me in Australia and in southern California. Ustalfs can do the same thing; they do in Venezuela, at least. As you go from the Ustalf or the Ustult to the Aridisol, the epipedon is first hard, massive and then soft. Experience generally can be utilized as a field criteria where you are just on the margins between ustic or xeric on one hand and aridic on the other. The intent was that it would avoid the necessity of forming judgements about which side of that boundary you were on. Focusing attention on it then causes people to make more observations. If I'd left it out, it wouldn't have been the subject of any studies whatever, even though it is aridic. We did the same thing between the Aridisols and the Mollisols. We said that if you had a mollic epipedon, a Mollisol could have an aridic moisture regime. And in the marginal area between the ustic and udic moisture regimes, we tried to use presence or absence of soft, powdery lime in the profile to put the soil in the Udalfs or Ustalfs. This was all done to avoid the necessity of actually determining the moisture regime. Now, certainly the presence or absence of soft, powdery lime is not a good marker between Udalfs and Ustalfs in non-calcareous parent materials, especially in regions where there is very little calcareous dust in the air. I suspect that several or most of these attempts are going to prove impractical once we've focused attention on them by putting them into Taxonomy, and we may have to modify them. It's going to make it more difficult to map. **Question 145, Minnesota**

10.16 Mollic Epipedon in Intertropical Regions

We have recognized while developing *Soil Taxonomy*, that in intertropical regions, the color value of the epipedon is not as well related to the carbon content as it is in temperate regions. We set up the suborder of Tropepts in order to avoid being tied by the distinction between umbric and ochric epipedons in the temperate soils. We have permitted a mollic epipedon in a number of the Tropepts if they have the characteristics of a vertic subgroup. it would be legitimate, in my judgement, to attempt to modify the definition of the mollic epipedon or of Mollisols where soils with mollic epipedons are associated with soils with similar epipedons, except for color, but have the same use potential. Precisely how to do it, I do not know. Some suggestions from those who are familiar with the soils in question would be essential in my judgement. **Question 27, Venezuela**

10.17 Thickness of Mollic or Umbric Epipedons in Typic Subgroups

The maximum thickness of the mollic or umbric epipedon for typic subgroups is not the same in all classes. For most frigid soils and Calciaquolls it is 40 cm, for ustic and xeric moisture regimes it is usually 50 cm, and for Haplaquolls and Hapludolls it is 60 cm. These depths were set by the correlation staff and others. For example, in Calciaquolls the base of the mollic epipedon rests on a calcic horizon with a dry color value of 6 or more. The upper boundary of the calcic horizon is usually above 40 cm. This same depth was considered to be appropriate to limit the thickness of the mollic epipedon in typic Borolls. Because these thicker than typical mollic epipedons were not caused by sedimentation, the soils with these thickened epipedons were classified in pachic subgroups.

We had the general principle that we would not use cumulic in soils with argillic horizons. If the landscape was stable enough, you had an argillic horizon. That, we thought, indicated too much stability for a cumulic subgroup. Well, you may have cumulic or pachic in the haplic great groups and only pachic in the argic great groups. Argiustolls can be pachic, Haplustolls can be cumulic or pachic. **Question 51, Minnesota**

We have provided a cumulic subgroup in the Haplaquolls, but not in the Argiaquolls. Now I presume this goes back to our general decision that we would not recognize cumulic subgroups, even though the mollic epipedon was thick, if the soil had an argillic horizon. This was on the theoretical grounds that the presence of an argillic horizon indicated more stability than the presence of a cambic horizon or the absence even of a cambic horizon. I think most of the Haplaquolls in Iowa would qualify as having a cambic horizon. But not all. The cumulic ones, probably not. The Typic Haplaquoll, I think, would have a cambic horizon. That would be something like a Webster. **Question 52, Minnesota**

10.18 Albolls

In Albolls, we use the albic horizon at the suborder level. The Albolls are Mollisols that have an albic horizon. The drainage is always impeded to some extent, but they are a group of Mollisols with an albic horizon, and they cover the range from somewhat poorly to poorly drained. They did not want to separate them in the classification, according to the judgment of the field men about how wet they were. The horizons were easy to recognize; one could always, I think, have no problem in getting agreement about the presence or absence of an albic horizon, but great problems about getting agreement about the drainage class; so by separating the Albolls at the suborder level, and giving priority to the albic horizon over the aquic moisture regime, we kept this natural group of soils together in the taxonomy.

Albolls are soils that are naturally wet at some season, and the variability between the best and the worst drained members of the Albolls is not particularly significant so far as one can see. **Question 89, Cornell**

Chapter 6 Soil Taxonomy

6.1 The system

If you tell someone you drive a Ford Ranger, the two words "Ford Ranger" convey considerable information to those who understand pick-up trucks. They will know the vehicle manufacturer, the size and shape of the vehicle, and will be able to make inferences regarding the quality of the vehicle. This is why we name and categorize things, including soils. To the initiated a soil name can convey considerable information. Soil Taxonomy is a system whereby we name, describe, and categorize soils. The system described here is the USDA system. Other systems are in use in various places around the world.

6.1.1 Soil Taxonomy is the USDA soil classification system. The smallest classifiable unit of soil is called a pedon. A pedon is a soil individual; it must be at least 1 m^2 in area. Smaller units are considered an anomaly or inclusion. A collection of contiguous similar pedons is a mapping unit. Soils are not discreet units like species--horses are distinctly different from cows. Soil taxonomy is more like rock taxonomy. One must establish a line, albeit artificial, to separate one class of rock from another, because in nature there exists a gradation in rocks from high concentrations of a particular element such as silicon to low concentrations of the element.

Soil ≠ a soil. A handful of soil is a handful of soil material. But a named soil, such as the Victoria clay, must have all components present to retain its identity. The ear of a horse is not a horse; it is just horse material. Similarly, if one holds a handful of material taken from the Victoria clay, the handful is not Victoria clay, only a sample from the Victoria clay. You might ask, why is this true, and why worry about such things? As an example, perhaps the Victoria clay is different from other clays because of a unique feature in the subsoil. If your handful of Victoria material came only from the topsoil, it contains none of the uniqueness of the Victoria clay.

6.1.2 Categories of the system. From most general to most specific, the categories of the taxonomy system are:

order
suborder
great group
subgroup
family
series

Originally, in 1975, there were 10 soil orders. The order now called Andisols was proposed in 1978 and adopted several years later. The twelfth order, Gelisols, was added in 1997. Detail 7-1 in the textbook briefly describes the soil orders. Each order contains in its name a formative element such as "oll" in Mollisols. These letters indicate the order Mollisols in the complete taxonomic name. Designation of the soil orders was more practical than logical. Similar soils were grouped together because of the observation that certain sets of conditions usually appear together. Certain landforms such as ice fields, rugged mountains, and salt flats are not classified and are not soil.

Orders are divided into suborders based on moisture, temperature or other features. Suborders are divided into great groups, great groups are divided into subgroups, subgroups are divided into family, and families are divided into series.

6.1.3 Soil series. More than 15,000 series are found in the U.S. The series name is the common name for a soil. All soils within a given series need not be contiguous. The Victoria clay can exist in multiple locations, many miles apart. Series are named for city or geographic feature. Series are sometimes subdivided into phases based on slope, texture or other practical feature; for example the Amarillo is divided into:

Amarillo loamy fine sand, 0-3% slope
Amarillo fine sandy loam, 0-1% slope
Amarillo fine sandy loam, 1-3% slope

6.1.4 Moisture regimes. Moisture regimes pertain to the amount of available water in control section of soil. In general, the control section is the layer of soil between where 2.5 cm and 7.5 cm of water would wet a dry soil. For a clay this section is typically the region between 8 and 25 cm deep; for a sand it is typically the region from 20 to 60 cm deep. The moisture regimes are:

Aquic: usually wet, prolonged periods of poor aeration
Udic: enough water throughout the year
Perudic: very wet, much percolation
Ustic: deficient sometime during the year, most rain comes in cropping season
Xeric: deficient during cropping season, most precipitation comes in winter
Aridic or Torric: very deficient, long dry periods, short wet periods

6.1.5 Temperature regimes. Temperature regimes are based on the mean annual soil temperature (MAST) at a depth of 50 cm (usually). Typically, the MAST is ~1 ^{0}C above mean air temperature. The temperature regimes are:

Pergelic: permafrost is present
Cryic: 0 ^{0}C - 8 ^{0}C, below 15 ^{0}C in summer
Frigid: 0 ^{0}C - 8 ^{0}C, above 15 ^{0}C in summer
Mesic: 8 ^{0}C - 15 ^{0}C, (47 ^{0}F - 59 ^{0}F)
Thermic: 15 ^{0}C - 22 ^{0}C
Hyperthermic: > 22 ^{0}C, (>72 ^{0}F)

Add the term "iso" if the soil is tropical and therefore temperatures experience minimal seasonal fluctuation. For example a tropical temperature regime with a MAST of 20 ^{0}C would be isothermic.

6.1. 6. Other terms are also used in taxonomy. Various formative elements are shown in Table 7-1 of the textbook. Particle size classes in the subsoil are sometimes used in family names, as are mineralogy classes.

6.1. 7. Complete taxonomy. The complete taxonomic name for the Wichita soil series is as follows: Wichita fine, mixed, thermic Typic Paleustalf. The series is Wichita; the family is fine, mixed, thermic (meaning: fine textured, mixed mineralogy, thermic temperature regime); the subgroup is Typic (meaning: typical); the great group is Pale (meaning: old); the suborder is ust (meaning: ustic moisture regime); and the order is alf (meaning: Alfisols). Similarly, the Lake Charles soil series is as follows:

Lake Charles fine, montmorillonitic, thermic Typic Pelluderts.

作业

1. 解释下列词汇：

Alb；Bor；Hapl；Pale；Pell；Ud；Ust；Xer

6.2 Soil Orders

The United States contains many thousands of soil series. However, all soils on earth fit into one of only twelve soil orders. The general characteristics of these twelve orders can be learned and remembered by a normal human mind. This lecture is intended to present the most important characteristics of each of the twelve soil orders. The orders re presented in the following order: first three rather exceptional orders are presented, then the other nine are described in order from youngest to oldest. A student would be wise to review Detail 7-1 in the textbook for a brief review of each order.

6.2.1. Gelisols. The syllable indicated Gelisols in the taxonomy name is "el". These soils have permafrost, and are found in Canada, Alaska, and Siberia.

6.2.2. Histosols. Histosols are indicated by the syllable "ist". These are organic soils, common in wet, swampy or marshy areas, especially if the climate is cold. These soils have unique properties, including low bulk density, strong acidity, and the tendency to subside over time, especially if drained. Plate 4 in the textbook (between pages 160 and 161) is of the suborder Hemist, a half-recognizable Histosol.

6.2.3. Andisols. Andisols are indicated by "and". These are volcanic soils, commonly found along the Pacific Rim. Unique properties of Andisols include low bulk density, the presence of amorphous clays, strong phosphorus retention, and very favorable water-holding properties. Plate 11 in the textbook is an Andisol from Hilo Hawaii.

This concludes the description of the three unique or exceptional orders. The remaining nine orders are presented from youngest to oldest, or from least to most developed.

6.2.4. Entisols. Entisols are indicated by "ent". These soils are recent deposits, or are not very developed because perhaps of a climate not conducive to soil development. No pedogenic horizons exist, except for a weak A horizon. These soils have great variability and are widely distributed. They are particulary common in the Rocky Mountains and on barrier barrier islands. Plate 3 in the textbook is of the suborder Psamment (sandy Entisol). Suborders include the following:

Aquents — wet
Arents — Ap horizon
Fluvents — alluvial parent material
Orthents — clay or loam
Psamments — sandy

6.2. 5. Inceptisols. Inceptisols are indicated by "ept". These soils are weakly developed, and are common in cool or dry climates, or in resistant or new parent material. These soils typically have a recognizable A horizon, but only a weak B horizon. Large regions of these soils are found in China, in the North Atlantic States, and in the Pacific Northwest. Plate 5 in the textbook is a inceptisols of the suborder Ochrepts. Suborders include the following:

Aquepts — wet
Ochrepts — light-colored topsoil
Plaggepts — man-made organic (i.e., manure) horizon
Tropepts — tropical climate
Umbrepts — acid, dark topsoil

6.2. 6. Aridisols. Aridisols are indicated by "id". These are dry-land soils, and are the most abundant soil type worldwide. Aridisols are light-colored, rich in carbonates, and are typically vegetated with bunchgrasses and shrubs. These soils are often quite productive when irrigated & fertilized. Plate 2 in the textbook shows an Aridisol of the suborder Argids. The suborders of Aridisols are:

Argids — argillic horizon
Calcids — calcic horizon
Cambids — cambic horizon
Cryids — very cold
Durids — duripan
Gypsids — gypsic horizon
Salids — salty

6.2.7. Mollisols. Mollisols are indicated by "oll". These are dark-colored prairie soils. This is the most common soil order in United States. These soils are typical of the great plains and of mountain valleys. Characteristics of Mollisols include the deep topsoil with a high base saturation. These soils are usually farmed, but native vegetation, when present, will be grasslands and savannas. Plate 6 in the textbook is a Mollisol from the suborder Udolls. The suborders of Mollisols are:

Albolls — E horizon

Aquolls — wet
Borolls — cold
Rendolls — lime & clay
Udolls — adequate water
Ustolls — dry in winter, moist in summer
Xerolls — dry in summer, moist in winter

6.2.8. Vertisols. Vertisols are indicated by "ert". These are self-mixing swelling clays. Vertisols are rather rare on a world scale but are common in India and Texas. Vertisols are fertile but are difficult to farm because of the wide and deep cracks that form when these soils are dry. Vertisols typically have no B horizon because these soils turn over rapidly--i.e., topsoil materials fall in the cracks and end up buried in the horizon. These soils provide poor physical support for roads and buildings because they are so unstable with swelling and shrinking. Native vegetation on Vertisols is grass. Plate 10 in the textbook is a Vertisol from the suborder Usterts.

6.2.9. Alfisols. Alfisols are indicated by "alf". These are highly productive forest soils, about equal in productivity to Mollisols. In comparison to Mollisols, Alfisols tend to have somewhat lower fertility because they are more leached, but they are more leached because they are found in regions receiving more rainfall than is typical for Mollisols. Alfisols are common in the American midwest and in eastern Europe. Because of their productivity and abundance, Alfisols are among the most important soils in the world. Alfisols have an argillic horizon. Vegetation is usually hardwood forest, as is typical of Indiana and Ohio. Plate 1 in the textbook is an Alfisol of the suborder Boralf. The suborders of Alfisols are:

Aqualfs — saturated seasonally
Boralfs — cold
Udalfs — adequate water
Ustalfs — dry in winter, moist in summer
Xeralfs — dry in summer, moist in winter

6.2.10. Spodosols. Spodosols are indicated by "od". These are sandy conifer forest soils, typical of New England and Scandinavia. These soils form in acid, sandy parent material. Spodosols have an E horizon with a spodic horizon beneath it. These soils are heavily leached, and are usually found in cold climates, although they are also found in Florida. Plate 8 in the textbook is a Spodosol of the suborder Orthod, indicated a typical Spodosol.

6.2.11. Ultisols. Ultisols are indicated by "ult". These are subtropical, humid-region soils, common in the southeastern United States and south east Asia. These soils are acidic and infertile, and have an argillic horizon. Ultisols are usually forest or pasture, but are also farmed for high value crops because Ultisols can be highly productive with substantial inputs of fertilizer, lime, etc. Plate 9 is an Ultisol of the suborder Udults, indicating an Ultisol with adequate moisture.

6.2.12. Oxisols. Oxisols are indicated by "ox". These are the oldest or most highly weathered soils. They occur in warm, moist tropical regions, and are most common in South America and Africa. These soils are dominated by oxide clays which are very infertile and difficult to manage. Plate 7 in the textbook in an Oxisol from the suborder Torrox, indicating an Oxisol with a relatively dry moisture regime.

作业：

1. 阅读下列的文章：

实验三、CATION EXCHANGE CAPACITY AND EXCHANGEABLE CATIONS BY AMMONIUM CHLORIDE

SCOPE

The methods for determination of Cation Exchange Capacity and Exchangeable Cations are those of Tucker (1974) and Tucker & Beatty (1974) with modifications to suit the Soil Conservation Service done by Craze & Doust (1980). This procedure is suitable for soils of pH ≥7.5.

The sample is washed with ethanol/glycol mixture to remove soluble salts, and the cations are displaced with alcoholic 1M NH_4Cl @ pH 8.5, followed by 0.05MNH_4Cl, then displacement of NH_4Cl with 15% KNO_3 + 6% $Ca(NO_3)_2$ solution.

The combined nitrate extract is analysed to determine the Cation Exchange Capacity (CEC) and the combined chloride extract is analysed to determine the Basic Exchangeable Cations.

SPECIAL APPARATUS

Atomic Absorption Spectrophotometer fitted with an Air/Acetylene burner and Hollow Cathode lamps to measure calcium, magnesium, sodium and potassium.

Shaker – a slow speed mixing machine rotating at 10 rpm with clips to hold the tubes at 30-40° to the horizontal.

Magnetic Stirrer.

pH Meter with temperature compensator.

Diluter/Dispenser.

Centrifuge, 3000 rpm.

Centrifuge Tubes (120 × 15 mm diameter and 15 mL capacity). High strength polythene with caps.

REAGENTS

(a) **Glycol/Ethanol Mixture**

Mix 100 mL Ethylene Glycol (Ethanediol) with 36 mL deionised water and bulk to 1 L with ethanol or methylated spirit.

(b) **Alcoholic 1M NH4Cl Solution (1 L)**

Dissolve 54 g NH_4Cl A.R. in 310 mL deionised water, add 665 mL ethanol. Stir or shake to expel dissolved air. Adjust to pH 8.5 with concentrated ammonia solution A.R.

Store in pyrex with a plastic stopper to exclude access of CO_2. Check the pH before use or prepare sufficient solution for immediate use only by proportioning the above quantities.

(c) **Alcoholic 0.05M NH_4Cl Solution**

Dissolve 2.70 g NH_4Cl (A.R.) in 330 mL deionised water and add 670 mL ethanol. Proceed as for 1M NH_4Cl.

(d) **K/Ca Nitrate Solution**

Dissolve 150 g KNO_3 A.R. in 800 mL deionised water, add 60 g $Ca(NO_3)_2.4H_2O$ A.R., dissolve and bulk to 1 L with deionised water.

(e) **4M HCl Solution**

Mix 200 mL concentrated HCl with 300 mL deionised water.

(f) **0.05M AgNO3 Solution**

Dissolve 8.5 g $AgNO_3$ A.R. in deionised water, add 1 drop conc. HNO_3 and bulk to 1 L with deionised water.

(g) **10% w/w K2CrO4 Solution**

Dissolve 10 g K_2CrO_4 in 90 mL deionised water.

(h) **Formol Reagent**

Mix 500 mL 35% formaldehyde with 500 mL deionised water. Adjust to pH 8.2 with NaOH solution. Check the pH of this solution before use and adjust if necessary.

(i) **Aqueous Acetone**

Mix 500 mL Acetone with 1 L deionised water.

(j) **0.02M NaOH Solution**

Weigh 12 g NaOH A.R. into a 250 mL beaker. Add 50 mL deionised water, mix, decant and repeat until the pellets are reduced by one third. Dissolve pellets in recently boiled and cooled deionised water and bulk to 1 L ($\approx$ 0.2M). Dilute this solution 1:10 with deionised water (treated as above) to prepare 0.02M NaOH.

(k) **0.05M NH4Cl Standard Solution**

Dissolve 2.675 g NH4Cl A.R. in deionised water, transfer to a 1 L volumetric flask and bulk to volume with deionised water.

(l) **Flaming Solution**

Dissolve the following in order in 800 mL deionised water:

12 g	Urea A.R.
20 mL	Perchloric Acid (70%)
1.25 g	$La(NO_3)_3.6H_2O$ A.R.
0.67 g	CsCl A.R.
50 mL	Ethanol

Bulk to 1 L with deionised water.

PROCEDURE

Removal of Soluble Salts

1. Dispense 10 mL glycol/ethanol mixture to the oven-dry equivalent of 1 g of air-dry (<2mm) soil contained in a centrifuge tube. Stopper the tube and mix on the shaker for 30 minutes. (Include at least one tube without soil for a blank.)
2. Centrifuge for 5 minutes at 3000 rpm. Discard supernatant.
3. Repeat (1) and (2) using fresh glycol/ethanol mixture. Ensure the soil pad is dispersed before mixing.

Preparation of Extracts

1. Add 10 mL 1M Alcoholic NH_4Cl, stopper the tube and mix for 30 minutes. Ensure the soil pad is dispersed before mixing.
2. Centrifuge for 5 minutes @ 3000 rpm and decant the clear supernatant into a 50 mL volumetric flask. Add the extracts from (3) and (4) to the same flask.
3. Repeat (1) and (2) with fresh 1M NH_4Cl solution.
4. Repeat (1) and (2) using 0.05M alcoholic NH4Cl solution.
5. Add 5 mL 4M HCl to the combined chloride extracts, bulk to 50 mL with 0.05M alcoholic NH_4Cl and mix.
6. Add 10 mL K/Ca nitrate solution to the centrifuge tube, disperse the soil pad and mix for 30 minutes. Centrifuge for 5 minutes @ 3000 rpm and decant the supernatant into a 50 mL volumetric flask.
7. Repeat (6), add the extract to the same flask, bulk to volume with the K/Ca nitrate solution and mix.

Analysis of Ammonium Chloride Extract (See Note.)

1. Set up and calibrate the AAS according to the manufacturer's instructions.
2. Dilute an aliquot of the chloride extract with flaming solution to adjust the concentration of the cation being measured to the linear concentration range of the instrument.
3. Aspirate the diluted extract into the flame of the AAS burner and record the absorbance reading. Determine cation concentration in mg/L from the calibration graph.

Analysis of K/Ca Nitrate Extract

(a) Procedure for Chloride Analysis

1. Pipette 20 mL of nitrate extract into a 250 mL conical flask.
2. Add 3 drops of 10% potassium chromate solution.
3. Titrate with 0.05M AgNO3 solution until the appearance of a permanent red-orange tint.
4. Record the volume of titrant consumed.
5. Determine reagent blank by repeating (1) to (5) and substituting 20 mL K/Ca nitrate solution for soil extract.
6. Add 20 mL 0.05M NH4Cl standard solution by pipette and repeat (3) and (4) to determine the concentration of the AgNO3 solution.

(b) Procedure for Ammonium Analysis

1. Pipette 20 mL of nitrate extract into a 250 mL beaker.
2. Add 8 mL formol reagent then 50 mL acetone/water reagent. Place the beaker with a small mixing bar on the stirrer.

3. Insert pH electrode, activate the stirrer and allow the pH to stabilise (approximately 2–3 minutes).
4. Titrate with 0.02M NaOH to pH 8.2 endpoint.
5. Record the volume of titrant consumed.
6. Determine reagent blank by repeating (1) to (5) but substituting 20 mL K/Ca nitrate solution for soil extract.
7. Add 10 mL 0.05M NH_4Cl standard solution by pipette and repeat (3) to (5) to determine the concentration of the NaOH solution.

CALCULATIONS

(a) Reagent Standardisation

Calculate and record concentration of the $AgNO_3$ solution.

$$\text{Molarity AgNO}_3 = \frac{V \times M}{T - B}$$

Where:
V = Volume of standard NH_4Cl solution (mL)
M = Concentration of NH_4Cl solution (mol/L)
T = Volume of $AgNO_3$ solution (mL)
B = Reagent blank (mL)

Calculate and record concentration of the NaOH solution.

$$\text{Molarity NaOH} = \frac{V \times M}{T - B}$$

Where:
V = Volume of standard NH_4Cl solution (mL)
M = Concentration of NH_4Cl solution (mol/L)
T = Volume of NaOH solution (mL)
B = Reagent blank (mL)

(b) Analysis of Nitrate Extract

Calculate and record the ammonium ion concentration.

$$Cl^-(meq) = (A - B) \times M \times 2.5$$

Where:
A = Volume of NaOH solution (mL)
B = Reagent blank (mL)
M = Concentration of NaOH solution (mol/L)
2.5 = Sampling factor
Where:
A = Volume of $AgNO_3$ solution (mL)
B = Reagent blank (mL)
M = Concentration of $AgNO_3$ solution (mol/L)
2.5 = Sampling factor

(c) Cation Exchange Capacity

Calculate and record the Cation Exchange Capacity.

$$CEC(meq/100g) = \frac{(A - B) \times 100}{W}$$

Where:
A = Concentration of ammonium ion in extract (meq)
B = Concentration of chloride ion in extract (meq)
W = Oven-dry sample weight (g)

(d) Exchangeable Cations

Calculate and record the Exchangeable Cation concentration.

$$M(meq/100g) = \frac{C \times D \times 5}{E \times W}$$

Where:

M = Concentration, in soil, of cation under test
C = Concentration of Cation in solution (mg/L)
D = Dilution factor. (See Analysis of Ammonium Chloride Extract, Step 2 on page 4.)
E = Equivalent weight of Cation under test (g)
W = Oven dry sample weight (g)

REPORTING THE RESULTS

Report the Cation Exchange Capacity and Exchangeable Cations results in meq/100 g to one decimal place.

REFERENCES

Craze, B & Doust, R 1980, *A Close Look at Tucker's Procedure for Determining Exchangeable Cations and Exchange Capacity,* Cowra Research Centre Technical Bulletin No 14.

Tucker, BM 1974, *Laboratory Procedures for Cation Exchange Measurement on Soils,* CSIRO Division of Soils Technical Paper No 23.

Tucker, BM & Beatty, HJ 1974, Exchangeable Cations and Cation Exchange Capacity*,* in Loveday, J (ed), *Methods for Analysis of Irrigated Soils*, Commonwealth Bureau of Soils Technical Communication No 54.

NOTE

AAS Instruments vary in sensitivity and degree of automation, so it is not possible to give detailed instructions on setting up for concentrations of standard solutions or for calibration procedures at each installation.

Chapter 7 N, P & K in the Soil Plant Environment

7.1 soil and the plant nutrition

Much of the management of soils hinges on the management of nitrogen (N) and phosphorus (P), and to a lesser extent, potassium (K). These three plant nutrients are consumed by plants in relatively large quantities, and are often limiting to plant growth. Thus they are a major item of commerce and of vital importance to the agriculture sector of the economy. What makes the management of nitrogen and phosphorus all the more critical is that they are among the most common non-point-source water pollutants.

7.1.1. Plant nutrients. Plants use N, P & K in large quantities. These plant nutrients, called the major plant nutrients, are commonly added as fertilizers. Nitrogen is by far the most widely applied plant nutrient. Plants also need the three secondary nutrients: calcium, magnesium and sulfur. These nutrients are used in moderately large amounts but are less likely to be limiting to plant growth, because their natural abundance is adequate for many crops. Plants also need at least seven micronutrients: boron, chlorine, molybdenum, copper, iron, manganese, and zinc. Some plants apparently either need or can benefit from other elements such as nickel, silicon, or sodium; but these are not considered to be generally essential elements for plant growth.

7.1.2. Sources of Soil Nitrogen. Ironically, 78% of the gas content in the atmosphere is N_2, yet the soil is usually low in N. We add N to the soil by various means. One way is called industrial fixation. This can be summarized by the equation: $N_2 + CH_4 \rightarrow NH_3$. This is the Haber process used to produce N fertilizer. The dinitrogen reactant is free, but the methane is a major expense. Not surprisingly, nitrogen fertilizer prices closely follow energy prices. Another source of soil N is lightning which produces some nitrate that falls in the rainwater. Symbiotic fixation is the most powerful natural way of adding N to soil. Plants in the Legume family (beans, peanuts, clover, etc.) produce nodules in their roots that house bacteria from the genus *Rhizobium*. The bacteria turn atmospheric N into ammonium, while the Legume feeds sugar to the bacteria. Alder trees have a similar relationship with an actinomycete, *Frankia.* Some free-living bacteria also fix atmospheric nitrogen and convert it to useful forms in the soil.

7.1.3. Nitrogen transformations. Soil nitrogen undergoes many changes. Those changes are illustrated by the following reactions:

Immobilization: NH_4^+ & NO_3^- $\rightarrow$ microbial biomass
Mineralization: organic-N $\rightarrow NH_4^+$
Nitrification: $NH_4^+ \rightarrow NO_3^-$
Denitrification: $NO_3^- \rightarrow N_2 + N_2O$

Immobilization removes N from the pool of plant-available N, at least temporarily, while the N resides in microbial cells. As these cells or other organisms decompose they release N through mineralization, most of which is accomplished by heterotrophic bacteria. Nitrification is done by autotrophic bacteria that obtain energy by oxidizing ammonium. These bacteria are ubiquitous, so the process of nitrification is not just a possibility, it is a probability. Therefore ammonium has a low persistence in soils. Denitrification occurs mainly in wet soils. In the absence in O_2, some bacteria will use nitrate as an electron acceptor in respiration. The end products are various nitrogen gases. In addition to these transformations, ammonium can be rather irreversibly adsorbed onto illite clay.

7.1.4. Nitrogen losses. Nitrogen is lost from the soil by various means. One has already by described, i.e., denitrification, in which nitrate exits as a gas. Another loss of nitrate occurs through leaching. This creates a serious pollution problem because of the toxicity of nitrate in drinking water. Ammonia, NH_3, is lost directly to the atmosphere through the process of volatilization. Through soil erosion N can be lost, usually in the form of NH_4^+ held onto soil surfaces by cation exchange. Finally, N is lost from the soil by harvest. The species consumed by plants are NH_4^+ & NO_3^-.

7.1.5. Phosphorus. Nature has provided no way to replenish phosphorus removed from soil.

For this reason, P is often deficient in the soil. It also has a low solubility, which helps keep it in the soil, but also keeps it relatively unavailable to plants. Phosphorus is used by plants and microbes as the orthophosphates:

PO_4^{3-}

HPO_4^{2-}

$H_2PO_4^-$

The form of orthophosphate that prevails is regulated by soil pH, with the more protonated forms dominating in lower pH environments. Phosphate absorbs strongly to soil (as indicated in Figure 10.10 in the textbook). Phosphate is commonly added to soil as fertilizer or organic residues. It is lost from the soil by erosion and harvest. Soil erosion results in phosphate pollution, as P-rich soil particles accumulate in bodies of surface water.

7.1.6. Potassium. As with phosphorus, nature provides no way to replenish soil potassium. Fortunately, K is naturally abundant in soils, and is quite persistent because of its low solubility. However, plants use large amounts of K^+. It is an exchangeable cation. Like ammonium it can absorb strongly to illite clay. Potassium is lost by erosion and harvest. Farmers often add K as a fertilizer. Unlike N or P, potassium is not a serious pollutant. It is rather easy to manage and inexpensive to purchase.

Students are encouraged to look up the following vocabulary words in the textbook glossary or elsewhere and to browse the following web sites.

作业

1. 解释下列词汇：

Nitrification；Denitrification；Mineralization；Volatilization；Leaching；Immobilization；Nitrate pollution；Phosphate pollution；Symbiosis；Potash

7.2 Plant Nutrition

As explained in Lecture 21, plants need more than just N, P and K. They need at least ten other nutrients. These other ten nutrients are briefly described in this lecture, as are various concepts related to soil fertility and plant nutrition.

7.2.1. Secondary nutrients. The secondary nutrients are calcium, magnesium, and sulfur.

Calcium is the most abundant of soil nutrients, and is environmentally benign. It is used by plants in large amounts, and is take up in the form of Ca^{2+}. It is an exchangeable cation, and typically dominates the cation exchange sites on soil.

Magnesium is less abundant than calcium and is used by plants in smaller quantities. The chemistry of magnesium is very similar to that of calcium. It is a divalent cation, used by plants as Mg^{2+}.

Sulfur, like nitrogen, exists in many forms and participates in many reactions. It is involved in various redox reactions, both as an electron donor (as is the case with elemental sulfur or organic sulfur forms), and as an electron acceptor (as is the case with sulfate). Sulfur is used by plants as the oxidized form, sulfate, SO_4^{2-}.

7.2.2. Micronutrients. Seven micronutrients are required by plants. These nutrients and the chemical form used by plants is given below:

Boron: H_3BO_3
Chlorine: Cl^-
Molybdenum: MoO_4^{2-}
Copper: $Cu^{2+,}$ Cu^+
Iron: Fe^{2+}, Fe^{3+}
Manganese: Mn^{2+}
Zinc: Zn^{2+}

In addition to the seven known micronutrients, other micronutrients may be required in such small quantities that the need has not yet been detected. Also, some elements are called "beneficials" because they improve plant performance, even though they may not be essential, or may be essential for only a few plants. For example, some grasses grow better with silicon than without; and clovers grow best with some cobalt in the soil, because the nitrogen-fixing bacterial than inhabit the roots of clovers need cobalt even though the clover itself does not.

7.2.3. Plant nutrient contents. Typical nutrient contents in plant shoots are given in the table below.

N 1.5 - 2%
P 0.2%
K 1.0%
Ca 0.5 - 1.0%
Mg 0.2%
S 0.1 - 0.2%
Cl 50 - 100 ppm
Fe 50 - 100 ppm
Mn 50 - 100 ppm
B 20 - 25 ppm
Zn 20 - 25 ppm
Cu 6 ppm
Mo 0.1 ppm

7.2.4. Acquisition by plants. Nutrients come into contact with plant roots by three mechanisms. They are mass flow, diffusion, and interception. Mass flow refers to the process that delivers nutrients to roots in the water that flows toward the root during transpiration. Enough calcium is delivered to roots by mass flow, so that no other mechanism is necessary. Diffusion is flow down a concentration gradient. Phosphorus is delivered in only minute amounts by mass flow, but is primarily delivered to roots through diffusion as plants keep the P concentration near zero at the root surface. Interception is the process in which the root intercepts nutrients by growing into the region where the nutrients are found.

Once the nutrient is in contact with the root, it can enter passively or actively. Passive uptake is typical of nutrients delivered primarily by mass flow. They simply enter the plants along with the water. The plant actively acquires some nutrients; in other words, the plant expends energy to actively pull nutrients into the root cells. Phosphorus and potassium are acquired actively.

7.2.5. Diagnostics. The fertility of soil can be evaluated by soil testing, plant tissue testing, or by the observation of visual symptoms. Soil testing is based on the idea that one can extract nutrients from the soil, measure the nutrients in the extract, and thereby predict how well the soil and supply nutrients to plants. This approach works well on annual crops for which soil testing is done prior to planting and fertilizing. Tissue testing is done on existing plants, and is therefore more useful for perennial plants than for annual crops that will only be in the field for a short time. The grower can perform simple tests, called "quick tests", or can collect samples to be sent to a lab that will perform thought tissue analysis after digesting and extracting all tissues. The grower can also learn to recognize visual symptoms, but symptoms are often misleading.

7.2. 6. Fertilizers. To the extent possible, growers do use, and should continue to use, organic waste materials such as manure to replace nutrients lost from the soil. Generally, these organic amendments are found to be inadequate for optimal yield, so commercial fertilizers are widely used. Most fertilizer N comes from the Haber process as described in the previous lecture. Fertilizer P comes from phosphate mines where rock phosphate is treated with acid to produce calcium or ammonium orthophosphates, and other materials. Potassium comes from underground salt mines, in situ mines, brines, and open-pit excavations.

7.2.7. Fertilizer grade. Fertilizers have a "grade" or "guarantee" that tells the user how much N, P and K are in the material. The standard notation is three numbers such as 18-46-0. This means 18% nitrogen, 46% phosphate equivalents, and 0% potash (as potassium is called in the fertilizer business). The nitrogen numbers are pure, actual percentages. The phosphate number is the percentage of P_2O_5 that would be present in the fertilizer if the phosphorus were P_2O_5 (which it is not). This notation is admittedly confusing and deceptive, but persists partly because it reports much larger P amounts than are actually present in the material. Actually percent P in the fertilizer is the middle grade number (46 in the above example) multiplied by 0.44. Similarly, potassium values are the percentage of K_2O that would be present in the fertilizer if the K in the fertilizer were K_2O (which it is not).

7.2.8. Fertilizer forms. Fertilizers can be in many forms. Many fertilizers are sold as blends of various dry fertilizers, mixed at the plant. Usually dry fertilizers are granulated for easy application in the field. One fertilizer, anhydrous ammonia, is applied as a gas. It is actually a liquid in the pressurized tank, but becomes a gas as it exits the tank. Liquid fertilizers have gained considerably in popularity. These are typically aqueous mixtures of various fertilizer ingredients. Liquid forms are easily and accurately applied. Micronutrients are often applied as chelates. This prevents them from reverting to unavailable forms in the soil. These micronutrients are often applied to the leaves of plants rather than to the soil.

7.2.9. Fertilizer application. Fertilizers can be applied before planting, either by broadcasting fertilizer over the field, or by injecting a gas or liquid in rows. Fertilizers are often applied at the time of planting, either by placing a row of fertilizer to the side and below the row of seed (called banding), or by adding fertilizer directly to the seed hopper (called pop-up). Application of fertilizer to plant leaves directly is called foliar feeding. Adding fertilizer to irrigation water is gaining in popularity and is called fertigation. Adding fertilizer to an existing crop such as a pasture is called topdressing.

Students are encouraged to look up the following vocabulary words in the textbook glossary or elsewhere and to browse the following web sites.

作业：

1. 解释下列词汇：

soil test；quick test；chelate；broadcast；banding；fertigation；foliar feeding；mass flow；diffusion；micronutrient；secondary nutrient

2. 阅读下列文章：

10.19 Argialbolls

The upper and lower part of a mollic epipedon may be separated by an albic horizon. This exception to the vertical continuity of the mollic epipedon was introduced to keep similar soils similarly classified. Some of the Argialbolls have an albic horizon within plow depth and some do not. Some of the cultivated ones, then, are going to lose their albic horizon the first time they are plowed. We don't want to change the classification because of plowing, as I have expressed a number of times. We do like to keep the similar soils together when they are marginal on the limit between taxa. The Argialbolls typically have a mollic epipedon that is thick enough to qualify without considering the nature of the argillic horizon below the albic horizon, but a few soils do have a very shallow albic horizon and/or a very thin one. The photograph on page 107, plate 1113, shows that the base of the albic horizon is about 25 cm. From the looks of it, it is about 15 cm to the top of the albic horizon. So if this got plowed just a little deeper than 25 cm, it would lose that albic horizon. Let's go to the Argialbolls to see how we handled that. We didn't specifically address that problem in the key to Albolls, page 273. If we mixed that whole albic horizon up it would drop out of Albolls, wouldn't it, by the present definition. It doesn't have a thick enough mollic epipedon, as an Al horizon, to qualify as a Mollisol. If we add the Al plus the upper part of the argillic horizon it would qualify as a Mollisol. **Question 101, Texas**

10.20 Calcic Horizon in Calciaquolls and Calciborolls

The calcic horizon of the Calciaquolls and the calcic horizons in your normal Borolls seemed to have different origins. The calcic horizon in the Calciaquolls, we thought, was due to capillary rise and evaporation from the surface. Whereas, in the Borolls, we thought the calcic horizon was due to downward-moving water and withdrawal of that water precipitating the carbonates. It's quite possible that you can have something that's halfway between. In theory, that could happen, you could get precipitation from capillary rise of a ground water, and you could also have downward movement at another season of the year of the carbonates stopping at about the same point. You could theoretically have a calcic horizon formed as a result of both processes instead of one or the other. But your problems would involve first, a proposal of a subgroup if you think it is necessary that you should have that. An aquic subgroup of Calciborolls is provided in *Soil Taxonomy* but has not been defined because no soils in this subgroup have been identified.

It is very common to find a distinct pattern to the calcic horizon - at the surface in North Dakota and perhaps in northern Minnesota. And in southern Minnesota, Iowa, Illinois they often have the shape of a donut, for example. Or depending on what I interpret to be the water depth, there may be a slight rise in an Aquoll, and you find the Calciaquoll on the rise instead of in the low part of the landscape. You can get it both ways. I've seen also rings in the landscape in the Dakotas where the calcic horizon has the shape of donut around the margins of the depression. Those rings are relatively higher than the bottoms of the depressions. How wet they are I don't have any personal knowledge because I have only seen them in the summers. Where gypsic and calcic horizons are associated, a decision must be made as to which is more important. I think that we took care of that in Taxonomy. It can happen and you then decide which one takes priority. **Question 201, Minnesota**

10.21 Borolls

The frigid Ustolls were changed to Borolls at the request of the Midwest Regional Technical Service Center, and I don't recall being in on much of the discussion about it. The potential reason is that it is simpler to control the soil moisture than it is the soil temperature and by putting all the Borolls together you have then a group of soils where one very limiting element is soil temperature. On that, is superimposed the moisture problem which we take care of at the subgroup level rather than the suborder level. In the *Seventh Approximation* most of the Borolls were Albolls.

The far-western mountain ranges have xeric moisture regimes in their soils at lower elevations. It was assumed that at higher elevations with a cryic soil temperature regime it is so cold that the soils would probably be udic even though the bulk of the precipitation comes in the form of snow in winter. The growing season is short enough when evapotranspiration is important, that the soil shouldn't be dry long enough to get into xeric or ustic moisture regimes. That was an assumption. If the moisture regime is xeric, a proposal for their classification will be needed. We did specify that the cold dry soils were not accommodated in *Soil Taxonomy* for lack of knowledge. **Questions 136 and 139, Minnesota**

10.22 Leptic Natriborolls

The Leptic Natriborolls were provided for because of the feelings of the correlators and the state soil scientists and the experiment station people, primarily in North Dakota and Montana, that they needed a distinction between soils with a very shallow solum and soils with a moderately thick solum. The northcentral regional correlation staff and the work-planning conferences went along with this desire for the Leptic subgroups. When we get to other kinds of soils where we are dealing with different groups of people, the feeling might not have been so strong or might have been absent about the importance of the thickness of what we used to call the solum. We are dealing with, not only different kinds of soil, but different groups or committees of people. **Question 122, Texas**

10.23 Vermiborolls

There's been considerable discussion about the point at which earthworm or faunal activity should be considered in *Soil Taxonomy. I* can give you an example from Europe, not from the U.S. There it is possible to maintain a soil under grass for some hundreds of years particularly in some of the Dutch orchards. And if you have a pit, you find the odd remnant of a blocky ped of an argillic horizon that has not been chewed up by worms as yet. I thought at one time, and still think, we probably need a 'Vermiorthent'. Professor Tavernier in the Near East has pointed out to me in conversation that many of the long-term irrigation soils are extremely wormy and that they need to be distinguished from the soils that have been irrigated for short periods and do not have the faunal activity. The irrigation in those soils is commonly with somewhat muddy water. You get fine stratifications that would make the soil an Entisol where there is no worm activity, but the worms destroy that within a matter of some hundreds of years at least. Now, I have not seen these soils, nor have I seen a description of them, but they came up for discussion at the International Correlation Conference that was held in Syria and Lebanon last summer. The proceedings of that conference will probably have something to say about these soils. In New Zealand I strongly considered the definition of a Vermic epipedon. There the agriculture is almost entirely pastoral on most of the two islands and the worms can multiply. They were introduced and they have multiplied under the permanent grass with high fertilization. They make a problem for us in that the epipedon is dark enough for a mollic epipedon, base saturation is high enough, and the dark colors extend to the depth at which the worms spend the winter. This is just in the neighborhood of the 25 cm that's required for a mollic epipedon. So we get these soils with an epipedon that is mollic to 26 or 27 cm. On the other side of the pit it's 24 cm thick. It's just on the 25 cm limit, and it's causing a problem in the application of *Soil Taxonomy* in New Zealand. It's entirely due to worm activity but an activity that terminates at about 25 cm, whereas the Vermiborolls of the steppes of Russia show intense worm mixing to depths of at least 2 meters. That's the thickness of the mollic epipedon in these soils of the Russian steppes. Those were the ones that caused us to establish the vermic great groups of Borolls, Udolls and Ustolls. We have all three in Europe. **Question 162, Minnesota**

The reason they have the intense earthworm activity in the Russian steppes and we don't see it here in our grasslands to that degree is because) they have another species of worm. This is the so-called rain-worm of Europe, which we do not have in the U.S. They have been introduced here now, but they were native there and as long as those soils remain under grass, there are enormous populations of earthworms in those soils. When they are cultivated, the population drops, but the evidence of their activity persists. That's *Lumbricus terrestris.* **Question 163, Minnesota**

The way the definition of the.vermic groups is written, the disturbance is due to animals but not necessarily to worms. If we begin to find significant numbers of soils that have been disturbed by other kinds of animals, then we might consider changing the formative element in the name from one suggesting worm to something else. What it would be, I would not know. We have a few soils in the U.S. where the disturbance has been due mostly to the prairie dog. I forget where I have seen these, I think Montana. But it was in the northwest somewhere where we have a loess over basalt, and everything has been mixed by burrowing mammals down to the basalt. **Question 164, Minnesota**

10.24 Rendolls

The Rendzinas of Europe form pretty much our central concept of Rendolls. Originally, Rendzinas were considered to be intrazonal soils whose characteristics are due to the parent material rather than to the climate and the vegetation. Rendolls are dark-colored soils resting mostly on marl in a humid climate. The Chernozems are not considered to be as Rendzinas. Some pedologists who visited Texas identified some of the dark-colored soils on limestone with an ustic regime as Rendzinas, although there was a marked difference in these soils from the Rendzinas of Europe, in that the Texas soils had a pronounced horizon of carbonate accumulation. These soils reflected then, the climate, not the bedrock. I found that the Texans had Rendzinas all over Texas wherever the soil was shallow on limestone. These would have been dark-colored soils irrespective of the nature of the rock, just as in Iowa, what was called a Prairie Soil, shallow over limestone, would have to be called a Rendzina because it had no horizon of carbonate accumulation. These would be quite unlike kinds of soil. However, variability at the suborder level could have been handled at the great group level. It was mostly to keep the grassland soils together and separated from the forest soils of the humid regions that we restricted the Rendolls to soils that have a udic moisture regime. The soils on limestone with ca horizons and an ustic moisture regime were then clearly separable from the Rendzinas of Western Europe.

Chapter 8 Soil Erosion and Water management

8.1. ***Soil Erosion***

Soil erosion has been our nation's most devastating environmental disaster. Soil in quantities of incomprehensible magnitude has been lost from the land where its forfeited productivity could have contributed to our national wealth. Instead, this soil has become sediment, plugging channels and raising riverbeds to levels that threaten human habitation along flood-prone rivers. In dryer climates this sediment becomes airborne dust, fouling the air-intake mechanisms of machinery and men. This lecture explores the nature of soil erosion, and methods of quantifying and controlling erosion.

8.1.1. Nature and extent of soil erosion. Natural or geologic erosion preceded farming. It has always occurred whether man was present or not. However, man and his farming practices have greatly accelerated erosion. In the corn belt, we presently lose about 1 pound of topsoil for every 0.67 pound of corn harvested. By some estimates about one half of America's topsoil was lost in the first 150 years of our nation's existence. The most dramatic series of events, those portrayed in the 1930s book and movie *Grapes of Wrath*, are collectively called the "dust bowl". Soil erosion is a two-fold problem:

loss of topsoil, often exposing the less productive B horizon

sediments that alter and elevate the course of rivers or pollute the air with dust

Soil erosion has two causes, wind and water. Wind erosion is most important in drier regions where it can proceed at staggering rates on dry, poorly vegetated soil. Water erosion is more important in wetter regions, including most of America's best farmland. In the United States soil erosion averages 5.6 ton/acre annually. Of this 3.1 tons/acre is caused by water, 2.5 tons/acre by wind.

8.1.2. Water erosion. Falling raindrops have considerable momentum as they hit the ground. These raindrops detach soil particles from peds. Raindrops falling at a rate of 30 ft/sec can move particles 150 cm laterally. Removing plant cover accelerates this detachment. Fine sands and silts are most easily detached. Detached particles are susceptible to transport. Sheet erosion is non-turbulent flow across the soil surface. Channelized flow is more destructive. Channelized, turbulent flow forms rills and gullies. Sheet and rill erosion is still rampant in the United States. The Universal Soil Loss Equation (USLE) was developed to predict sheet and rill erosion.

8.1.3. Predicting water erosion. The USLE developed in 1965 is still used by the USDA's Natural Resource Conservation Service (NRCS). The USLE has the following form:

$A = R \times K \times LS \times C \times P$

where,

A = predicted actual annual erosion in tons/acre

R = rainfall intensity factor, such as 550 in New Orleans, 35 in Salt Lake City

K = erodibility based on texture and structure (see Table 15-1 in the textbook)

LS = length-slope both length of slope and degree of slope are important. Of the two, degree of slope is the more important. For example:

1000 ft field with 0.5% slope: LS = 0.15

1000 ft field with 20% slope: LS = 12.9

C = cover and management. These are complex local values based on crop, tillage, and timing. Some examples include:

continuous fallow C = 1.0

permanent grass pasture C = 0.003

typical row crop C ~ 0.4

P = practice such as contouring or strip cropping

To use the USLE, one finds through actual measurements and tabulated data the appropriate value for each factor, then multiples the five factors together to find "A", the predicted actual annual erosion.

Other models in use include:

RUSLE — Revised Universal Soil Loss Equation; more precise than USLE

WEPP — Water Erosion Prediction Project

8.1.4. How much erosion is too much? Theoretically, we could afford to lose soil at the rate at which soil forms. The USDA default position is that soil forms at the rate of 1 inch per 30 years. This assumption may be nearly true for some soils, but many soils form much more slowly than this. Nevertheless, soil erosion evaluation is generally based on the assumption that 1 inch of soil loss per 30 years is acceptable.

1 acre-inch of soil weighs about 167 tons. If 167 tons form in 30 years, the annual soil formation rate is 5.6 ton/year. 5 tons erosion per acre per year is generally considered tolerable.

So, the question arises, how can farms stay within the tolerable level of erosion? Farmers cannot change the R factor or the K factor. Management hinges of the LS factor, the C factor, and the P factor. Most attention is given to the C factor because changing the C factor can dramatically change the predicted "A" value, often with only minimal cost to the farmer (see Table 15-3 in the textbook).

8.1.5. Wind Erosion. In the presence of wind, soil moves by suspension (particles <0.05 mm are suspended in moving air), saltation (particles between 0.05 and 0.5 mm in diameter move in short hops along the soil), and creep (particles between 0.5 and 1.0 mm move along the soil without leaving the surface).

Wind erosion is negligible east of the Mississippi but can be extreme in arid western regions. Nevada farmland averages 22 ton of erosion per acre annually. Dryland soils have less vegetation, less clay, less moisture and are therefore readily eroded. To make matters worse, eroded soils are more coarse and therefore more draughty. This downward spiral in arid soil quality is called desertification.

Factors affecting soil erosion by wind are assessed by the Wind Erosion Equation (WEQ). Factors in the WEQ are:

soil erodibility
surface roughness
climate
length of field
vegetative cover

The vegetative cover factor is the most manageable factor (see Figure 15-17 in the textbook) and is the factor usually addressed by farmers attempting to minimize wind erosion.

8.1.6. Soil Conservation. In actuality we only know of four powerful, practical tools for soil conservation. Those tools are: conservation tillage (to leave more residue on soil), pesticides (to minimize need for tillage), nutrient management (to enhance vegetative growth), and vegetative buffers (to protect surface waters from sediments).

Students are encouraged to look up the following vocabulary words in the textbook glossary or elsewhere and to browse the following web sites.

作业

1． 解释下列词汇：

rill；gully；suspension；saltation；creep；geologic erosion；conservation tillage

8.2. Water Management

To a great extent, the availability of water determines the economic value and productivity of land. Indeed, in some water-deficient western counties, the water rights that allow the holder to irrigate the land are worth more than the land. Even the most casual naturalist can easily observe the generality that where rainfall is abundant, plant life is abundant. This lecture touches on the subject of water management as it relates to soil.

8.2.1. Soil water balance sheet. Water enters and exits the surface layers of soil. One can keep a balance sheet to tally up incoming and outgoing water, thus quantifying or predicting the amount of water available in the soil.

Water In includes:
- precipitation
- irrigation
- run-on

Water out includes:
- run-off
- percolation
- evaporation
- transpiration

Adding all water in, then subtracting all water out, yields net soil water. One can then attempt to optimize these factors to improve amounts of soil water. Some factors are more manageable than others. Irrigation is the most direct and powerful tool. Most of the U.S. water supply is used for irrigation.

8.2.2. Water resources. Many countries have insufficient water supplies. Some examples follow.

U.S. has 2.6 million gal of accessible water per person
Mexico has 1.0 million gal/person
Jordan has 42,000 gal/person
Israel has 98,000 gal/person
½ million gal/person is a critical threshold

Fresh water sources include polar ice caps, surface water (lakes, rivers), and ground water (much more plentiful than surface water).

8.2.3. Water depletion. Many important sources of water are becoming severely depleted. The Ogallala aquifer is about 24% depleted. Irrigated acreage above the Ogallala has declined 34% since 1974. The Gulf Coast has 60% overdraft (60% more out than in). The Mexico City aquifer has poor quality water and land above the aquifer has subsided about 7 meters. The water level drops 1 meter/year. Nearly an identical story is unfolding in Beijing. Ownership of many river waters is disputed. Ethiopia plans to divert Nile water. Syria diverts Euphrates river water. In the western U.S., water rights are presently being sold to cities, and well permits are controlled.

8.2.4. Irrigation is still important. Although only 16% of world's cropland irrigated, irrigated acres produce 30% of our food. See Tables 16-2 and 16-3 in the textbook for specific irrigation data.

8.2.5. Water quality for agriculture. Water quality for irrigation is affected by some minor factors such as BOD, turbidity and temperature. The more important factors are salinity, sodicity, and toxic substances.

Salinity in water can lead to saline soil. Salinity is measured by electrical conductivity (EC) in the units of decisiemen/meter (dS/m). A useful relation is: dS/m × 640 » ppm total soluble solids. Plants differ in salt tolerance. Normally one does not want over 2 dS/m for irrigation. Irrigation usually results in salt build-up in the soil. This problem is managed by applying a leaching fraction (see Figure 16-6 in the textbook).

Sodicity in water can create a sodic soil that is impermeable to subsequent additions of irrigation or rainwater. Sodicity is evaluated by sodium adsorption ratio (SAR). SAR values over 9 can indicate a problem. SAR is often adjusted for bicarbonate because bicarbonate precipitates calcium from the soil-water system:

$OH^- + HCO_3^- + Ca^{2+} \rightarrow CaCO_3 + H_2O$

Specific ions and other materials can be toxic to plants or to the organism that consumes the plants. Cl, B, and Na are the most likely culprits. The toxicity of these elements depends on the irrigation method used. See Table 16-6 in the textbook for water quality standards.

8.2.6. Methods of Irrigation. Furrow irrigation is an old method used by native Americans before white settlers inhabited the land. This method is still used for small fields, and high-value crops. Sprinkler irrigation made major gains in acreage during the third quarter of this century. Sprinklers can be configured to pivot about a central point thereby irrigating a large circle such as a quarter-section, can be lateral traveling systems, or can be stationary. The present trend in sprinklers is towards Low Energy Precision Applicators (LEPA) which direct the water more precisely to the plant in need, rather than throwing water into the air where much of it evaporates. Microirrigation, long popular in desert lands such as Israel, is gaining popularity in the United States. Micro irrigation includes various forms of drip and trickle emitters that deliver water under highly controlled conditions. This method is conducive to high water-use efficiency. Each irrigation method has unique management requirements.

Students are encouraged to look up the following vocabulary words in the textbook glossary or elsewhere and to browse the following web sites.

作业：

1. 解释下列词汇：

Aquifer；Ogallala；leaching fraction；salinity；sodicity；SAR；EC；furrow；microirrigation BOD； turbidity

2. 阅读下列文章：

实验四、AVAILABLE PHOSPHORUS: BRAY NO 1 EXTRACT

CAUTION: This procedure involves the use of hazardous chemicals. Refer to laboratory safety guidelines before proceeding.

SCOPE

This test outlines the procedure for the determination of available phosphorus in soils. Bray No. 1 solution is designed to extract adsorbed forms of phosphate only and is for use with soils with a pH <7.5.

PRINCIPLE

Phosphorus is extracted from the soil using Bray No 1 solution as extractant. The extracted phosphorus is measured colourimetrically based on the reaction with ammonium molybdate and development of the 'Molybdenum Blue' colour. The absorbance of the compound is measured at 882 nm in a spectrophotometer and is directly proportional to the amount of phosphorus extracted from the soil.

SPECIAL APPARATUS

Centrifuge (6 000 rpm).

Diluter/Dispenser (Brand Diluette® Cat No 7046 54).

High strength centrifuge tubes with caps (15 mL capacity).

Spectronic 20 photometer with 10 mL tubes.

REAGENTS

Bray No 1 Extracting Solution

Dissolve 2.22 g Ammonium Fluoride A.R. (NH_4F) in deionised water and transfer to a 2 L volumetric flask. Add 5 mL concentrated hydrochloric acid and bulk to volume with deionised water.

Reagent A

Dissolve 17.14 g ammonium molybdate A.R. [$(NH_4)_6Mo_7O_{24}.4H_2O$] in 200 mL of warm deionised water. Dissolve 0.392 g potassium antimonyl tartrate A.R. ($KSbO.C_4H_4O_6$) separately in 150 mL deionised water. Place 500 mL deionised water in a 2 L volumetric flask and slowly add 200 mL concentrated sulphuric acid with mixing. When cooled, add the cooled molybdate and tartrate solutions, then mix and bulk to volume with deionised water.

Reagent C

Dissolve 0.53 g L-Ascorbic Acid A.R. ($C_6H_8O_6$) in deionised water and transfer to a 500 mL volumetric flask. Add 70 mL of Reagent A and bulk to volume with deionised water. Prepare fresh a volume of this solution sufficient for the day's work by proportioning the above quantities.

Standard Phosphorus Solution (P $\equiv$ 50 mg/L)

Dissolve 0.2195 g potassium dihydrogen orthophosphate A.R. (KH_2PO_4) in 100 mL deionised water, transfer to a 1 L volumetric flask, add 5 mL concentrated sulphuric acid (A.R.) and bulk to volume with deionised water.

Phosphorus Working Standard (P $\equiv$ 2.50 mg/L)

Pipette 5 mL standard phosphorus solution into a 100 mL volumetric flask and bulk to volume with deionised water.

PROCEDURE

1. Dispense 7 mL Bray Extracting Solution into the oven-dry equivalent of 1 g of air-dry soil contained in a centrifuge tube. Include one tube containing the Bray Solution only for the blank.
2. Stopper the tube and shake vigorously for 1 minute.
3. Transfer the tubes to the centrifuge and spin at 6 000 rpm for 5 minutes.
4. Dispense 0.50 mL of the supernatant plus 2.0 mL Reagent C into a colourimeter tube. Mix and stand for 30 minutes.
5. Prepare a set of reference standards from the 2.50 mg/L phosphorus solution using the diluter/dispenser and the following table as a guide:

DILUTION TABLE FOR STANDARDS

DILUTION TABLE FOR STANDARDS

mls 2.5mg/L Ref.	mls Reagent C	Phos. Conc. (µg/2.5 mL)	Typical Absorbance Value
0.05	2.45	0.125	0.06
0.10	2.40	0.250	0.09
0.20	2.30	0.500	0.17
0.30	2.20	0.750	0.26
0.40	2.10	1.000	0.34
0.50	2.00	1.250	0.40

6. Set instrument zero (∞ Abs.) and then set full scale (zero Abs.) using the blank solution prepared above.
7. Measure and record the absorbance of the standards and samples at wavelength 882 nm.
8. Prepare a chart or graph from the standards data to plot phosphorus concentration against absorbance, or derive the equation of the line of best fit using linear regression. Use the chart or equation to determine the phosphorus concentration in the sample solutions.

CALCULATIONS

Calculate Available Phosphorus content.

$$\text{available phosphorus} = (mg/kg) = \frac{C \times 14}{ODW}$$

Where:

C = Phosphorus concentration from chart/equation (µg/2.5 mL)
ODW = Oven-dry sample weight (g)
14 = Dilution factor

REPORTING THE RESULTS

Report the Bray No 1 available phosphorus results in mg/kg as a whole number.

REFERENCES

Bartlett, GN, Craze, B, Stone, MJ & Crouch, R (ed) 1994, *Guidelines for Analytical Laboratory Safety*. Department of Conservation & Land Management, Sydney.

Bray, RH & Kurtz, LT 1945, Determination of total, organic, and available forms of phosphorus in soils. *Soil Science*, 59: 39-45.

Menage, PMA & Pridmore, B 1973, Automated determination of phosphate using Bray No 1 Extractant. CSIRO Division of Soils. *Notes on Soil Techniques*, pp80-82.

Chapter 9 Wetlands and Drainage

Wetlands were once quite universally considered a nuisance, to be drained and made farmable. Recently we have come to recognize the value of wetlands and the need to protect them. Not all drainage projects impinge on wetlands. Often, irrigated land benefits from subsurface drains that allow removal of salt. In certain other instances, drainage is a practical solution to a land management problem. This lecture is a brief introduction to the nature of wetlands and the technology of land drainage.

9.1. What are wetlands? 32% of America's cropland has been artificially drained. The present farm bill dictates no net loss of wetlands. However, land drained before 1985 can stay drained, and wetlands can be drained if a landowner creates an equal amount of wetlands on his or her property from land that is not presently wetlands. The U.S. Army corps of Engineers has jurisdiction over wetlands in the United States.

By definition, a wetland is an area of predominantly hydric soil that can support a prevalence of water-loving plants. Wetlands include swamps, marshes, bogs, etc. The hydric soil criterion is a problematic one. Scientists disagree on what should constitute a hydric soil. Presently the USDA publishes a national hydric soils list. The Federal register says: "Hydric soils are defined as soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part." Note that whether or not the land is wet is not the criterion for designation of a legal or jurisdictional wetland.

Indicators of hydric soils include:

organic soil
histic epipedon
sulfidic material
gleyed horizon, chroma less than 2
aquic moisture regime
poorly drained soils
low redox potential

Wetland delineation is scientifically and politically difficult. One can assume that most landowners do not wish for their land to be designated jurisdictional wetlands because such a designation restricts the use of the land.

9.2. Beneficial functions of wetlands. Wetlands serve many purposes useful to man and to the environment as a whole. Some benefits are listed below:

Preserving biodiversity
Recharging groundwater
Regulating flow to control flooding
Providing pressure against saltwater intrusion
Buffering against storms and waves
Catching sediments
Retaining nutrients
Removing toxins
Producing medicinal plants
Providing wildlife habitat
Producing fuel products
Maintaining gene bank
Producing specialized crops such as rice and cranberries.

9.3. To drain or not to drain. New drainage on undrained, jurisdictional wetland may be illegal by the Swampbuster Act of 1985. Landowners can maintain or redo existing drains. Landowners may drain one tract of wetland and create a wetland elsewhere. Just as the benefits from wetlands are undeniable, so are the benefits from drainage. Upland crops generally do very well on drained wetlands. Such lands are typically fertile, contain considerable clay, and have more uniform moisture characteristics than undrained lands. Also drained lands are better than wetlands for most engineering purposes. Many plots of land are not jurisdictional wetlands, but are wet enough to benefit from artificial drainage. Irrigated land is often drained to control salinity.

9.4. Drainage methods. The method one would chose to drain land depends on the needs of the landowner (see Table 17-4 in the textbook).

Subsoil drainage is accomplished using buried pipes or tubes. Many years ago, most such drains were made of tile. Some times the term "tile drains" is still used to designate subsurface drains. Subsurface drainage lowers a water table. Some soils will not drain, as explained below.

drainage capacity should be 10 or more
drainage capacity = % pore space (dry) - % qv (@ FC)
most sands and loams will drain
the Sharkey clay swells when wet; drainage capacity < 0

In some cases vertical drains connected to horizontal underground drain lines can be used to drain a wet spot. Subsurface drains require an outlet. In regions lacking the infrastructure for drainage, drainage may be impossible for lack of ditches in which to discharge the water.

Surface drainage is done to remove surface water. this can be accomplished by field smoothing, but construction of open ditches, or by using bedding or ridge-till farming systems.

Students are encouraged to look up the following vocabulary words in the textbook glossary or elsewhere and to browse the following web sites.

作业：

1. 解释下列词汇：

Wetlands；redox；hydric；aquic；chroma；tile drains；gleyed

2. 阅读下列文章：

实验五 SOIL MOISTURE CONTENT

SCOPE

This method covers the laboratory determination of the moisture content of a soil as a percentage of its oven-dried weight. The method may be applied to fine, medium and coarse grained soils for particle sizes from 2 mm to >10 mm.

PRINCIPLE

The method is based on removing soil moisture by oven-drying a soil sample until the weight remains constant. The moisture content (%) is calculated from the sample weight before and after drying.

SPECIAL APPARATUS

For fine-grained soils (maximum particle size 2 mm) A thermostatically controlled oven preferably of the forced-draught type, capable of maintaining a temperature between 105 °C and 110 °C.

A balance readable and accurate to 0.01 g. (See Note 1.)

Numbered aluminium weighing tins with close fitting numbered lids. A suitable size is 75 mm diameter and 25 mm deep.

A desiccator containing anhydrous self-indicating silica gel. A suitable size is 250 mm diameter. For medium-grained soils (maximum particle size 10 mm)

An oven as specified above.

A balance readable and accurate to 0.2 g. (See Note 1.)

Suitable airtight corrosion-resistant container of about 400 g capacity.

A scoop.

For coarse-grained soils (maximum particle size >10 mm)

An oven as specified above.

A balance readable and accurate to 1 g. (See Note 1.)

Suitable corrosion-resistant container of about 3.5 kg capacity.

A scoop.

PROCEDURE

For fine-grained soils

1. Clean and dry the weighing tin+lid and weigh to 0.01 g (W1). (See Note 2.) Select a representative quantity of moist soil in the amount specified by a test. Where not otherwise specified use at least 30 g. Place the sample in the weighing tin and replace lid. Weigh the tin and contents to 0.01 g (W2). (See Note 3.)
2. Remove the lid and place the tin with contents and lid in the oven and dry to constant weight between 105 °C and 110 °C. (See Notes 4 and 5.)
3. Remove the tin with contents from the oven, replace the lid and place the whole in the desiccator to cool. (See Note 6.)
4. Weigh the tin and contents to 0.01 g (W3). (See Note 7.)

For medium-grained soils

1. Clean and dry the container and weigh to 0.1 g (W1). (See Note 2.) Place a sample of about 300 g of soil in the container, replace the lid and weigh to 0.1 g (W2).
2. Remove the lid and place the container and lid in the oven and dry between 105 °C and 110 °C (see Notes 3 and 4) to a constant weight. (See Note 5.)
3. After drying, remove the container from the oven, replace the lid and allow to cool.
4. Weigh the container with contents to 0.1 g (W_3).

For coarse-grained soils

1. Clean and dry the container and weigh to 1 g (W1). Place a sample of about 3 kg of soil in the container and weigh to 1 g (W2).
2. Place the container in the oven and dry between 105 °C and 110 °C (see Notes 3 and 4) to a constant weight. (See Note 5.)
3. After drying, remove the container from the oven and allow to cool.
4. Weigh the container with contents to 1 g (W_3).

CALCULATIONS

Calculate the moisture content of the soil as a percentage of the dry soil weight.

$$MC\% = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Where:

W_1 = Weight of tin (g)

W_2 = Weight of moist soil + tin (g)S

W_3 = Weight of dried soil + tin (g)

Where chemical analyses are performed on moist (air-dry) samples, it is convenient to correct the results to an oven-dry basis by use of an appropriate Moisture Factor (MF) calculated as follows:

$$MF = \frac{W_2 - W_1}{W_3 - W_1} \times 100$$

or

$$MF = 1 + \frac{MC}{100}$$

REPORTING THE RESULTS

Report the moisture content of the soil to three significant figures. (See Note 4.)

REFERENCE

Standards Association of Australia. *AS 1289 B1.1-1977. Determination of the Moisture Content of a Soil: Oven Drying Method (standard method).*

NOTES

1. The balance to be used in a particular test will depend on the size of the sample. The balance should be accurate to within 0.03% of the weight of the sample.

2. It is convenient to maintain a table of weighing tin weights. Weighing tins should be thoroughly cleaned and re-weighed at least every 6 months. If tins become dirty or tarnished, they should be thoroughly cleaned immediately and re-weighed.

3. The sample may be crumbled to assist drying but care is necessary to avoid loss of any soil.

4. Soils containing gypsum lose water of crystallisation on heating. Therefore, a moisture content determined by this method will be affected by approximately 0.1% for each 1% of gypsum. If it is suspected that gypsum is present in the soil, dry the moisture content samples at not more that 80 °C, for a longer period and report the method used.

5. Checking every moisture content sample to determine that it is dried to a constant weight is impractical. In most cases, drying of a moisture content sample overnight (16 hours) is sufficient. In cases where there is doubt concerning the adequacy of overnight drying, drying should be continued until the difference in weight of the cooled sample after two successive periods does not exceed 0.1% of the original sample weight. Samples of sand may often be dried to constant weight after 7 hours. Since dry soil may absorb moisture from wet samples, dried samples should be removed before placing wet samples in the oven. Drying time should be extended if the oven is full.

6. If the lids of the tins fit well and it is unlikely that the samples are to be left for a considerable time before weighing, the samples need not be placed in the desiccator to cool.

7. Moisture content samples should be discarded and should not be used in any other test.

Chapter 10 Soil Surveys

Shortly after World War II, the United States undertook an ambitious project to map, describe and inventory all soils in the nation. The methods for completing this task have evolved over time. The end result is a collection of Soil Surveys for most counties in the U.S. Some counties still have not been surveyed, and a few are presently being surveyed. These published Soil Surveys are of tremendous value to agriculture and to urban land users.

10.1. Who and Why? The National Cooperative Soil Survey was organized in 1952. This organization is a part of the USDA NRCS (formerly SCS). The U.S. Forest Service, BLM, and other federal and state agencies often cooperate in the production of Soil Surveys. The surveys are done to describe, evaluate and inventory soils. Each soil in a county is evaluated for its agronomic capability and its limitations for urban uses. It is also named and classified according to the system of soil taxonomy. Most U.S. counties have been surveyed, some twice. Crews work on a survey (usually one county) for a period of about 5 years.

10.2. Rating Soils. Soils are rated for agricultural capability and are placed into one of eight Capability Classes. The classes are described below:

Class I land can be used continuously for intensive crop production with good farming practices.

Class II land has more limitations than Class I land for intensive crop production, due to such characteristics as moderately steep slopes (2-5%).

Class III land has severe limitations and requires more special conservation practices than Class II land to keep it continuously productive. For example, the land may have shallow soil, slopes of about 6-10%, or shallow water tables.

Class IV land has severe limitations for cropping use and needs a greater intensity of conservation practices for cultivated crops than Class III land. Most of the time this land should be in permanent crops such as pastures.

Class V land is not likely to erode but has other limitations, such as boulders or wetness, which are impractical to correct, and thus the land cannot be cultivated. It should be used for pasture, range, woodland, or wildlife habitat.

Class VI land is suitable for the same uses as Class V land, but it has a greater need for good management to maintain production because of such limitations as steep slopes or shallow soils.

Class VII land has very severe limitations and requires extreme care to protect the soil, even with low intensity use for grazing, wildlife, or timber.

Class VIII land has such severe limitations (steep slopes, rock lands, swamps, delicate plant cover) that it can be wisely used only for wildlife, recreation, watersheds, or aesthetic appreciation.

Capability classes are divided into subclasses that identify the limiting factor for the soil. The Capability Subclasses are used as IIe, meaning, the land is Class II with "e" limitation. The symbols used and their meanings are:

e	erosion (50% of U.S. land)
s	shallow, stony, droughty, permafrost (25%)
w	wetness (17%)
c	climate (5%)

About 3% of land has no limitation for agricultural use.

Soils are also evaluated for engineering purposes. For examples see Table 20-5 in the textbook for dwellings, Table 20-6 for lawns and golf courses, and Table 20-7 for topsoil.

10.3. Contents of Soil Survey. A typical soil survey contains soil information provided in a systematic way. The surveys usually begin with general information about the area, such as history, climate, and geology. The survey will illustrate typical patterns of soil in the landscape. The surveys usually describe each soil twice; once in layman's terms, and again in more technical terms. Soil Survey books usually contain about 20 tables of data describing each soil in terms of physical properties (such as texture and bulk density), chemical properties (such as pH and salinity), water properties (such as water holding capacity), etc. The back of the survey books is a collection of maps drawn onto aerial photographs. These maps are usually on a scale of 1:24000, which means that one inch on the map equals 24000 inches on the ground.

10.4. Benchmark soils. Some soils are more important than others. Those soils that are extensive and of greater than average importance are designated as Benchmark Soils. In the U.S. about 1000 of our 15,000 series are benchmark soils. These soils are studied intensively. Examples of Benchmark Soils include:

Sharkey, Aquept in LA
San Joaquin, Xeralf in CA
Palouse, Xeroll in WA
Beltsville, Udult in MD
Amarillo, Ustalf in TX

Students are encouraged to look up the following vocabulary words in the textbook glossary or elsewhere and to browse the following web sites.

作业

1. 解释下列词汇：

Land Capability Class
Benchmark soil
Soil survey

10.2 Land-use Planning

Americans place a high value on property rights. We consider the right to own, buy, sell, and control land to be an indispensable ingredient for personal freedom. At the same time, we have at times found that our neighbors have used their property in ways we find offensive, so we have relinquished some rights and given our government the right to control in large part the way land can be developed and used. Often the allowable use for a piece of land depends on the unique capabilities of that land.

10.2.1. Food as a National Priority. Americans want food supplies to be stable, wholesome, and inexpensive. Filling this order poses serious challenges. These challenges can be understood in light of a few important facts:

farmable acres are declining
yield growth per acre is no longer increases annually as it once did
population is increasing
the world's standard of living is increasing creating a demand for more food, especially meat

The demand for more meat is particularly onerous because many pounds of grain or hay are consumed to produce a pound of meat. One might well ask, where will future food increases come from? Experts generally agree that more food could be derived from the deserts and tropics. However, the deserts are deserts because they lack water. Water to irrigate deserts is becoming more scarce. Farming the tropics is problematic because of low soil fertility, tremendous pest pressure, and unstable politics. Most of our efforts to date have centered on increasing yields from land that is presently farmed. This can include "ordinary" farmland, prime farmland, or unique farmland.

10.2.2. Non-agricultural Land Use. Each soil is uniquely suitable for use. In the Soil Survey program of the NRCS, each soil is evaluated for a multitude of possible uses. These uses are listed below:

crops
rangeland/timber
wildlife habitat

recreational development, including, camp sites, picnic areas, playgrounds, paths and trails, golf courses, building site development, including, shallow excavations, dwellings (basements), small commercial buildings, streets, lawns and landscaping;

sanitary facilities, including septic tank fields, sewage lagoons, landfill sites, landfill cover,

construction materials, including roadfill, sand, gravel, topsoil

water management, including pond reservoirs, embankments, dikes, levees, drainage, irrigation terraces, grassed waterways

10.2.3. Controlling Land Use. The Homestead Act of 1862 provided for the allocation of 160 acres to a settler if he remained on the land for 5 years. Perhaps this was one of our earliest attempts at social engineering, encouraging citizens to change their residence and life style. Similar acts followed. The Zoning Act of 1926 allowed government control of property. The Supreme Court ruled that such urban control was justified under the maxim, "Use your own property in such a manner as not to injure another." Although not the original intent, some states zone rural land too.

In addition to zoning laws, governments use various other tools to control land use. One such tool is differential taxation. This concept is based on the idea that property taxes should be based on current use of the land, not its highest use or market value. This system discourages development and tends to keep land in agriculture. Laws based on this idea are sometimes called "greenbelt" laws. This is the most commonly used technique to preserve farmland.

Another way to control land use is through easements. With an easement one purchases the right to a specific land use, but ownership of land is not transferred.

In 1926 another landmark change was enacted--the Eminent Domain law. This law allowed for forced sales of property against the will of the property owner. The doctrine behind this law is that the general welfare prevails over private good. When this law is exercised, the landowner receives market value for his or her property.

Public purchase and private purchases also allow control of land use. Public purchases can be voluntary or involuntary. Basically, the government purchases land to insure a specific use. Private purchases of land are done by concerned citizens or organizations to protect land or preserve a particular organism or feature. The Nature Conservancy is an example of an organization that purchases land to preserve it.

Students are encouraged to look up the following vocabulary words in the textbook glossary or elsewhere and to browse the following web sites.

作业

1. 解释下列词汇：
   eminent domain
   zoning
   easement
2. 阅读下列文章：

实验六、SOIL MOISTURE CONTENT

SCOPE

This method covers the laboratory determination of the moisture content of a soil as a percentage of its oven-dried weight. The method may be applied to fine, medium and coarse grained soils for particle sizes from 2 mm to >10 mm.

PRINCIPLE

The method is based on removing soil moisture by oven-drying a soil sample until the weight remains constant. The moisture content (%) is calculated from the sample weight before and after drying.

SPECIAL APPARATUS

For fine-grained soils (maximum particle size 2 mm) A thermostatically controlled oven preferably of the forced-draught type, capable of maintaining a temperature between 105 °C and 110 °C.

A balance readable and accurate to 0.01 g. (See Note 1.)

Numbered aluminium weighing tins with close fitting numbered lids. A suitable size is 75 mm diameter and 25 mm deep.

A desiccator containing anhydrous self-indicating silica gel. A suitable size is 250 mm diameter.

For medium-grained soils (maximum particle size 10 mm)

An oven as specified above.

A balance readable and accurate to 0.2 g. (See Note 1.)

Suitable airtight corrosion-resistant container of about 400 g capacity.

A scoop.

For coarse-grained soils (maximum particle size >10 mm)

An oven as specified above.

A balance readable and accurate to 1 g. (See Note 1.)

Suitable corrosion-resistant container of about 3.5 kg capacity.

A scoop.

PROCEDURE

For fine-grained soils

1. Clean and dry the weighing tin+lid and weigh to 0.01 g (W1). (See Note 2.) Select a representative quantity of moist soil in the amount specified by a test. Where not otherwise specified use at least 30 g. Place the sample in the weighing tin and replace lid. Weigh the tin and contents to 0.01 g (W2). (See Note 3.)
2. Remove the lid and place the tin with contents and lid in the oven and dry to constant weight between 105 °C and 110 °C. (See Notes 4 and 5.)
3. Remove the tin with contents from the oven, replace the lid and place the whole in the desiccator to cool. (See Note 6.)
4. Weigh the tin and contents to 0.01 g (W3). (See Note 7.)

For medium-grained soils

1. Clean and dry the container and weigh to 0.1 g (W1). (See Note 2.) Place a sample of about 300 g of soil in the container, replace the lid and weigh to 0.1 g (W2).
2. Remove the lid and place the container and lid in the oven and dry between 105 °C and 110 °C (see Notes 3 and 4) to a constant weight. (See Note 5.)
3. After drying, remove the container from the oven, replace the lid and allow to cool.
4. Weigh the container with contents to 0.1 g (W_3).

For coarse-grained soils

1. Clean and dry the container and weigh to 1 g (W1). Place a sample of about 3 kg of soil in the container and weigh to 1 g (W2).
2. Place the container in the oven and dry between 105 °C and 110 °C (see Notes 3 and 4) to a constant weight. (See Note 5.)
3. After drying, remove the container from the oven and allow to cool.
4. Weigh the container with contents to 1 g (W_3).

CALCULATIONS

Calculate the moisture content of the soil as a percentage of the dry soil weight.

$$MC\% = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Where:

W_1 = Weight of tin (g)

W_2 = Weight of moist soil + tin (g)S

W_3 = Weight of dried soil + tin (g)

Where chemical analyses are performed on moist (air-dry) samples, it is convenient to correct the results to an oven-dry basis by use of an appropriate Moisture Factor (MF) calculated as follows:

$$MF = \frac{W_2 - W_1}{W_3 - W_1} \times 100$$

or

$$MF = 1 + \frac{MC}{100}$$

REPORTING THE RESULTS

Report the moisture content of the soil to three significant figures. (See Note 4.)

REFERENCE

Standards Association of Australia. *AS 1289 B1.1-1977. Determination of the Moisture Content of a Soil: Oven Drying Method (standard method).*

NOTES

1. The balance to be used in a particular test will depend on the size of the sample. The balance should be accurate to within 0.03% of the weight of the sample.
2. It is convenient to maintain a table of weighing tin weights. Weighing tins should be thoroughly cleaned and re-weighed at least every 6 months. If tins become dirty or tarnished, they should be thoroughly cleaned immediately and re-weighed.
3. The sample may be crumbled to assist drying but care is necessary to avoid loss of any soil.
4. Soils containing gypsum lose water of crystallisation on heating. Therefore, a moisture content determined by this method will be affected by approximately 0.1% for each 1% of gypsum. If it is suspected that gypsum is present in the soil, dry the moisture content samples at not more that 80 °C, for a longer period and report the method used.
5. Checking every moisture content sample to determine that it is dried to a constant weight is impractical. In most cases, drying of a moisture content sample overnight (16 hours) is sufficient. In cases where there is doubt concerning the adequacy of overnight drying, drying should be continued until the difference in weight of the cooled sample after two successive periods does not exceed 0.1% of the original sample weight. Samples of sand may often be dried to constant weight after 7 hours. Since dry soil may absorb moisture from wet samples, dried samples should be removed before placing wet samples in the oven. Drying time should be extended if the oven is full.
6. If the lids of the tins fit well and it is unlikely that the samples are to be left for a considerable time before weighing, the samples need not be placed in the desiccator to cool.
7. Moisture content samples should be discarded and should not be used in any other test.

ORGANIC CARBON

CAUTION: This procedure involves the use of hazardous chemicals. Refer to laboratory safety guidelines before proceeding.

SCOPE

Estimates of total organic carbon (OC expressed as C) are used to assess the amount of organic matter in soils. The method measures the amount of carbon in plant and animal remains, including soil humus but not charcoal or coal. Levels are commonly highest in surface soils but wide variations from almost zero to above 15% C are possible. Presence of Cl will produce a positive interference in saline soils (>0.5% Cl). The bias resulting from the presence of Cl can be corrected if required.

PRINCIPLE

The determination of soil organic carbon is based on the Walkley-Black chromic acid wet oxidation method. Oxidisable matter in the soil is oxidised by 1 N K2Cr2O7 solution. The reaction is assisted by the heat generated when two volumes of H2SO4 are mixed with one volume of the dichromate. The remaining dichromate is titrated with ferrous sulphate. The titre is inversely related to the amount of C present in the soil sample.

APPARATUS

Hot plate with simmerstat control or electric nest as used in macro-nitrogen determinations or bunsen burner with tripod and gauze.

Heat-resistant sheet on which to cool flasks.

Fume cupboard.

10 mL automatic zero pipette or syringe pipette.

CAUTION: If using an ordinary pipette, use a rubber pipette filler to suck up the potassium dichromate solution which is poisonous.

20 mL measuring cylinder or syringe pipette for dispensing concentrated sulphuric acid. 250 mL dry erlenmeyer (conical) flasks. 250 mL tall form beakers can be used as an alternative to erlenmeyer flasks for potentiometric titration. 200 °C thermometer.

50 mL burette or automatic titration unit.

1000 mL volumetric flask.

100 mL volumetric flask.

REAGENTS

1 N Potassium Dichromate

Dissolve 49.040 g K2Cr2O7 AR (dried at 105 °C) in deionised water, transfer to a 1 L volumetric flask and make to volume with deionised water.

Sulphuric Acid 98% w/w

This should be used fresh from the bottle and not left standing in a burette or beaker, as it rapidly picks up moisture from the air. It is satisfactory until the strength falls to <96%.

0.4 N Ferrous Sulphate

Dissolve 112 g FeSO4.7H2O in 800 mL deionised water containing 15 mL concentrated H_2SO_4. Dilute to 1 L with deionised water and store in a dark bottle.

"Ferroin"

Dissolve 1.485 g O-phenanthroline monohydrate and 0.695 g ferrous sulphate in approximately 80 mL deionised water, then dilute to 100 mL. Store in a dark bottle away from light.

PROCEDURE

1. Determine the moisture content of the air-dry soil which has been ground to pass a 0.42 mm sieve. (See Soil Moisture Content P1A/1.) Weigh accurately enough soil to contain between 10 mg and 20 mg of carbon into a dry tared 250 mL conical flask (between 0.5 g and 1 g for topsoil and 2 g and 4 g for subsoil). (See Note 1.)

2. Accurately add 10 mL 1 N $K_2Cr_2O_7$ and swirl the flask gently to disperse the soil in the solution. Add 20 mL concentrated H_2SO_4, directing the stream into the suspension. Immediately swirl the flask until the soil and the reagent are mixed. Insert a 200 ℃ thermometer and heat while swirling the flask and the contents on a hot plate or over a gas burner and gauze until the temperature reaches 135 °C (approximately ½ minute). (See Note 2.)

3. Set aside to cool slowly on an asbestos sheet in a fume cupboard. Two blanks (without soil) must be run in the same way to standardise the FeSO4 solution.

4. When cool (20–30 minutes), dilute to 200 mL with deionised water and proceed with the $FeSO_4$ titration using either the "ferroin" indicator or potentiometrically with an expanding scale pH/mV meter or autotitrator.

"Ferroin" Titration

Add 3 or 4 drops of Ferroin indicator and titrate with 0.4 N $FeSO_4$. As the end point is approached, the solution takes on a greenish colour and then changes to a dark green. At this point, add the ferrous sulphate drop-by-drop until the colour changes sharply from blue-green to reddish-grey. (See Note 3). If the end point is overshot, add 0.5 or 1.0 mL of 1 N $K_2Cr_2O_7$ and reapproach the end point drop-by-drop. Correct for the extra volume added. If over 8 mL of the 10 mL dichromate have been consumed, the determination must be repeated with a smaller soil sample.

Manual Potentiometric Titration

1. Set an expanded scale pH/mV meter with a platinum electrode and calomel reference electrode to read E(mV). Insert the electrodes and temperature compensator in the solution and

stir with a magnetic stirrer. Tall form beakers can be used as an alternative to conical flasks giving more room for the electrodes, temperature compensator and burette.

2. Using one of the unknowns, plot a titration curve by recording values of measured E(mV) and mL titrant (0.4 N $FeSO_4$) added from a burette. The end point is then found on the point of inflexion on the curve (approximately 750 mV). Subsequent titrations are simply discontinued when this point is reached, and the corresponding titrant consumption is then measured. If over 8 mL of the 10 mL has been consumed, the determination must be repeated with a smaller soil sample.

Automatic Potentiometric Titration

Use an autotitrator with a platinum electrode to the mV terminal and calomel reference electrode to the glass electrode terminal. Use a 25 mL autoburette for the 0.4 N $FeSO_4$ titrant. The titration is carried out by first plotting a titration curve as described above and then automatically titrating to the end point (approximately 750 mV) thus determined. Titrator settings are as follows: proportional band 2, delay 5 seconds, direction of titration downscale, burette speed 1.

If over 8 mL of the 10 mL dichromate has been consumed, the determination must be repeated with a smaller soil sample.

CALCULATIONS

From the equation:

$$2Cr_2O_7^{2-} + 3C + 16H^+ \rightarrow 4Cr^{3+} + 8H_2O + 3CO_2 \uparrow$$

1 mL of 1 N Dichromate solution is equivalent to 3 mg of carbon. Where the quality and normality of the acid/dichromate mixture used are as stated in the method, the percentage carbon is determined from the following:

$$\text{Organic Carbon (\%)} = \frac{0.003g \times N \times 10 \times mL \times (1 - T/S) \times 100}{ODW}$$

$$= \frac{3(1 - T/S)}{W}$$

Where:

N = Normality of $K_2Cr_2O_7$ solution

T = Volume of $FeSO_4$ used in sample titration (mL)

S = Volume of $FeSO_4$ used in blank titration (mL)

ODW = Oven-dry sample weight (g)

REFERENCES

Allison, LE in Black, CA et al. 1965, *Methods of Soil Analysis*, pp1372-1378.

Bartlett, GN, Craze, B, Stone, MJ & Crouch, R (ed) 1994, *Guidelines for Analytical Laboratory Safety*. Department of Conservation & Land Management, Sydney.

McLeod, S 1973, Studies on wet oxidation procedures for the determination of organic carbon in soils. CSIRO Division of Soils, *Notes on Soil Techniques,* pp73-79.

NOTES

1. Ferrous iron in soils, if present, leads to high results for the dichromate-ferrous sulphate titration. However, soil samples that have been air-dried for 1 or 2 days contain insignificant amounts of soluble iron compounds, even though ferrous iron had been high in the fresh sample. Where the chloride content of the soil is high, some interference will occur. This can be suppressed by the addition of silver sulphate to the concentrated sulphuric acid at the rate of 15 g/L. In most cases, chloride affect can be ignored as a chloride content of 1%, for example which is a very high figure, would result in an error of only about 0.1% in the organic carbon content. Nitrates up to 5% and carbonates up to 50% do not interfere in the determination.

2. It is important that heat be removed when the digesting solution reaches 135° C as the dichromate thermally decomposes at 150 °C causing significant errors.
3. Some soils adsorb "Ferroin" indicator and it might be necessary to filter using a rapid filter paper.
4. Comparative tests of this procedure carried out by CSIRO Division of Soils and NSW Department of Mineral Resources have shown that a correction factor for recovery of carbon is not required. The effect of charcoal in the soil on organic carbon is unresolved. If charcoal is present, it should be noted or, if desired, removed before testing.