

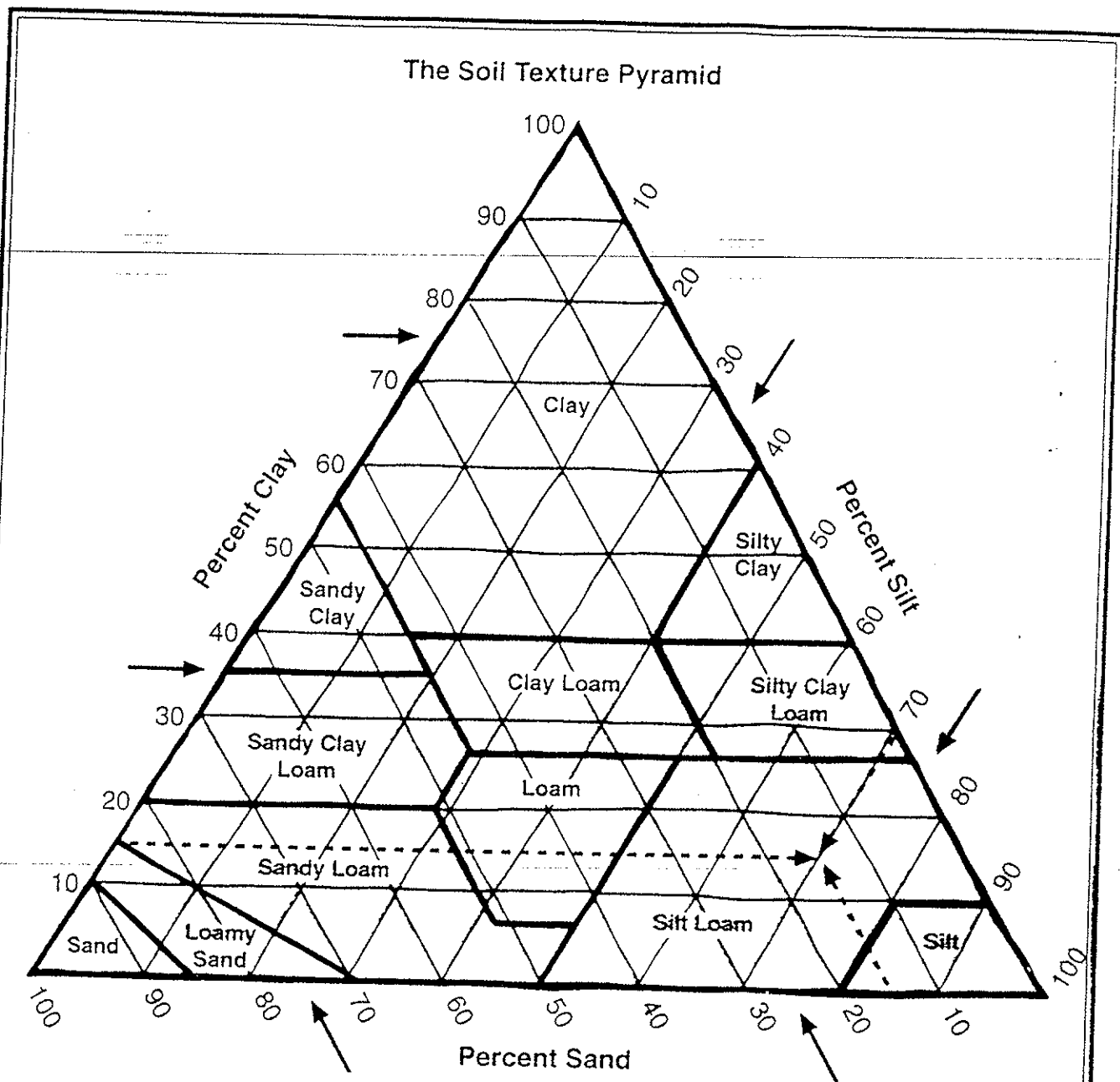
Down and Dirty

Soil is one of the three indicators that help you determine where a wetland is. There are spaces between the mineral and organic components of soil that are filled with air or water. As the soil becomes saturated, these air spaces become filled with water. Gas exchange between the water in the soil and the air above the soil is slower than the rate at which the oxygen in the soil is used up. Millions of bacteria, fungi, protozoa, arthropods, worms, and others use up this air in their daily existence. Once this air is used up, the only microorganisms able to live are those that do not need oxygen. There are many kinds of bacteria that make use of elements such as nitrogen and sulfur instead of oxygen. These anaerobic processes change the color, texture, and even the smell of the soil. Because wetland soils are usually saturated, they become **anoxic** (without oxygen). Looking at the soil's physical and chemical characteristics can therefore provide clues about whether or not a soil is anoxic for long periods of time.

Soil color is identified using three components: hue, value, and chroma. **Hue** measures the soil color in relation to red, blue, yellow, and so on. **Value** indicates lightness of the hue. **Chroma** refers to the strength of the color. For the purposes of looking for a wetland soil, only the chroma is very important. To determine soil color, scientists use a book that contains paint color chips that can be compared against a soil sample. In matching the color of the soil to the color of one of the chips, you can determine what the value, hue, and chroma of a soil are. These soil color books are produced by Munsell (see address on page 62). You may be able to find them in your local library.

Soil texture is used to further describe a soil and also consists of three components: **sand**, **clay**, and **silt**. These components are distinguished by their size and shape. Determining texture is a subtle technique and requires practice. A **loam** is a soil that has equal parts of sand, clay, and silt. Soil texture is described in terms of the three components. For example, a clay loam has a little more clay than silt or sand. Scientists use a soil pyramid to help them describe soil texture. By estimating the percent of each component and then looking at the pyramid, they can give a standardized description of soil texture that other scientists will understand. Texture affects drainage of a soil. Generally, the sandier a soil, the quicker it will drain. Generally, the more clay a soil has, the slower it will drain.

When wetland soils are almost always saturated, the microorganisms living in the soil do not have a chance to fully decompose dying plant material before all of the oxygen is used up. Gradually over time, the plant material is compacted and built up, forming a layer on top of the original soil. In some wetlands this layer is so deep that the wetland you currently see is no longer in contact with the original mineral soil. Layers of soil that are made up of mostly plant matter are known as **organic soils**. An organic soil can be an indication of a wetland.



The major soil textural classes are defined by the percentages of sand, silt, and clay according to the heavy boundary lines shown on the textural pyramid. If these percentages have been determined for a soil sample by particle size analysis, then the pyramid can be used to determine the soil textural class name that applies to that soil sample. To use the graph, first find the appropriate clay percentage along the left side of the pyramid, then draw a line from that location across the graph going parallel to the base of the pyramid. Next, find the sand percentage along the base of the triangle, then draw a line inward, going parallel to the side of the pyramid labeled "silt." The small arrows indicate the proper direction in which to draw the lines. The name of the compartment in which these two lines intersect indicate the textural class of the soil sample. Percentages for any two of the three soil separates is all that is required. Because the percentages for sand, silt, and clay add up to 100 percent, the third percentage can easily be calculated if the other two are known. If all three percentages are used, the three lines will all intersect at the same point. For example, a soil sample that contains 15 percent sand, 15 percent clay, and 70 percent silt is indicated by the dashed lines that intersect in the compartment labeled "silt loam."

Activities:

Field Notes: Determining Soil Type

Before you begin this activity, be certain to change into field clothes, since you will get very dirty. To start, you need a shovel, a squeeze bottle with water, a Munsell soil color book, and a meter stick. Record all of your observations using the "Taking Field Notes" format.

1. Go outside and choose three places where you think the soil might be different from one another and where it is okay if you dig holes. Good places would be at the edge of a pond, on the top of a hill, and in a field, for example. Using the shovel, dig a 40 cm (16 in.) deep hole. Be sure to fill the hole back in once you are done with the activity so no one gets hurt. Look closely at the top layers of the soil. Is it dark in color? Is it fibrous, and can you see bits of plant material? These are indicators that a soil is organic. If the soil is very sandy, look for a black layer that might be a sign of organic matter.
2. Scoop a chunk of soil from the bottom of the pit. Break it in half (so the colors are not blurred) and using the color chart, compare the **matrix** (dominant background) color with color chips until a match is determined, and record the answer. Soil colors are always recorded hue/value/chroma (10YR5/2). Make observations about the smell of the soil. A smell like rotten eggs (Hydrogen sulfide) is an indicator of anaerobic soil conditions. If more than 50 percent of the top layers of the soil are **organic** (plant and animal materials), then the soil is a wetland soil. If a soil is **gleyed** (gray color indicated by pages in the color chart), or if the soil matrix chroma is less than two with mottles or one without mottles, then it is a wetland soil. A **mottled soil** has one dominant color with specks of another color.
3. To determine the soil texture, grab a new piece of soil and squish it between your thumb and first finger (you may need to wet it slightly). If it forms a very smooth ribbon, it is a silty soil. If a ribbon forms but has cracks, it is a clay soil. If no ribbon forms at all, it is a sandy soil. Wet the soil until it is very soupy and rub it around in your hands. If it is sticky, there is clay in it. If it is very slippery, there is silt in it. If it is gritty, there is sand in it.
4. At this time, it is also convenient to record information about hydrology. If water is seeping into the pit, record the depth to which the pit fills. If the water is within 12 inches of the surface, wetland hydrology is present. Just because there is not water in the pit when you are there does not mean that water is not there sometimes. You have to look for other clues about hydrology. Some indicators of wetland hydrology are:
 - Drainage patterns—depressions where water flows.
 - Drift lines—lines of leaves, branches, sediment, and so on deposited on the ground.
 - Water marks—lines on trees, rocks, etc., caused by ponded water.
 - Gauge data—government agencies, universities, and others usually keep track of water levels over a period of time for major water bodies.

Name: _____ Date: _____

For the Student:

1. How did soil color differ among your three soil pits?

2. How did soil texture differ among your three soil pits?

3. What other observations were you able to make about the soils in your pits, and how did they differ from one another?

4. Did you find any wetland soils?

5. What observations about wetland hydrology were you able to make? Did you see water in any of your soil pits? If so, how far from the soil surface was the water surface? If not, did you see any other indications of wetland hydrology?

INTRODUCTION

Soils are the natural materials through which plants receive five of the six essential factors necessary for their growth [see Figure 1]. Plant growth is dependent upon a favourable combination of these factors and any one of them which is out of balance with the others can reduce or even prevent the growth of plants. The principle of limiting factors states that the level of crop production can be no greater than that allowed by the most limiting of the essential plant growth factors. Human's living standard is often determined by the quality of the soils as they provide the basis for food production, fibre production, and a healthy and beautiful environment.

In order to understand soil and its effects on plant growth, we will be examining:

- its formation;
- its major components;
- the manner in which it provides plants with essential elements; and
- the problems of soil management, especially under the intensive forms of agriculture which exist today in Ontario.

CHAPTER 1:

SOIL FORMATION AND PROFILE

Soil Formation is a function of abiotic factors [climate, parent material, topography] and biotic factors [living organisms] all operating through time. The ways in which these five factors interact will determine the kind of soil that is made [see Figure 1:1].

Climate The effects of climate help to weather rocks and contribute to soil formation. Much of the influence of climate is due to the measure of control which it exerts over both the type and growth pattern of vegetation, and the amount of moisture which moves through the material.

Parent Material The parent material is the material from which soil is formed. It may be the original rock of the area or, as with almost all Ontario soils, it may have been transported there by glaciers, streams or wind. The minerals that make up the rocks will give soils different characteristics. For example, soils developed on sandstone are sandy while those on shale are clayey.

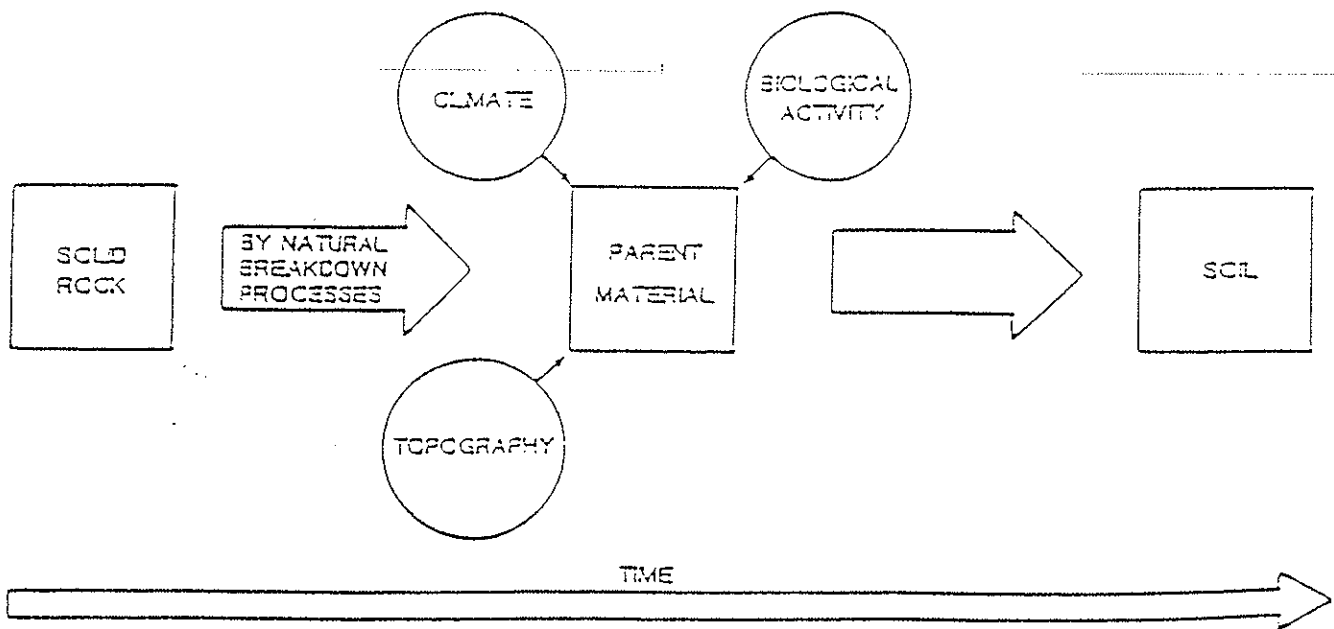


Figure 1:1 Soil formation - A two phase process

Topography

The topography of the land refers to the way it is shaped. It ranges from flat plains to rolling hills, or steep mountains. Both the length and steepness of a slope have important effects on soil formation. On flat land the soil may have a uniform thickness, whereas valleys may have thick layers and the surrounding hills little or no soil. This is due to soil being transported, mainly by water, down the hillside.

Time

Time is extremely important in the formation of soil. It takes a very long time to produce an inch of topsoil. It may take as little as one hundred years or as long as ten thousand years, depending on the interaction of the above factors. While soil is formed slowly, it can be quickly washed or blown away due to poor management or natural disaster.

Living Organisms

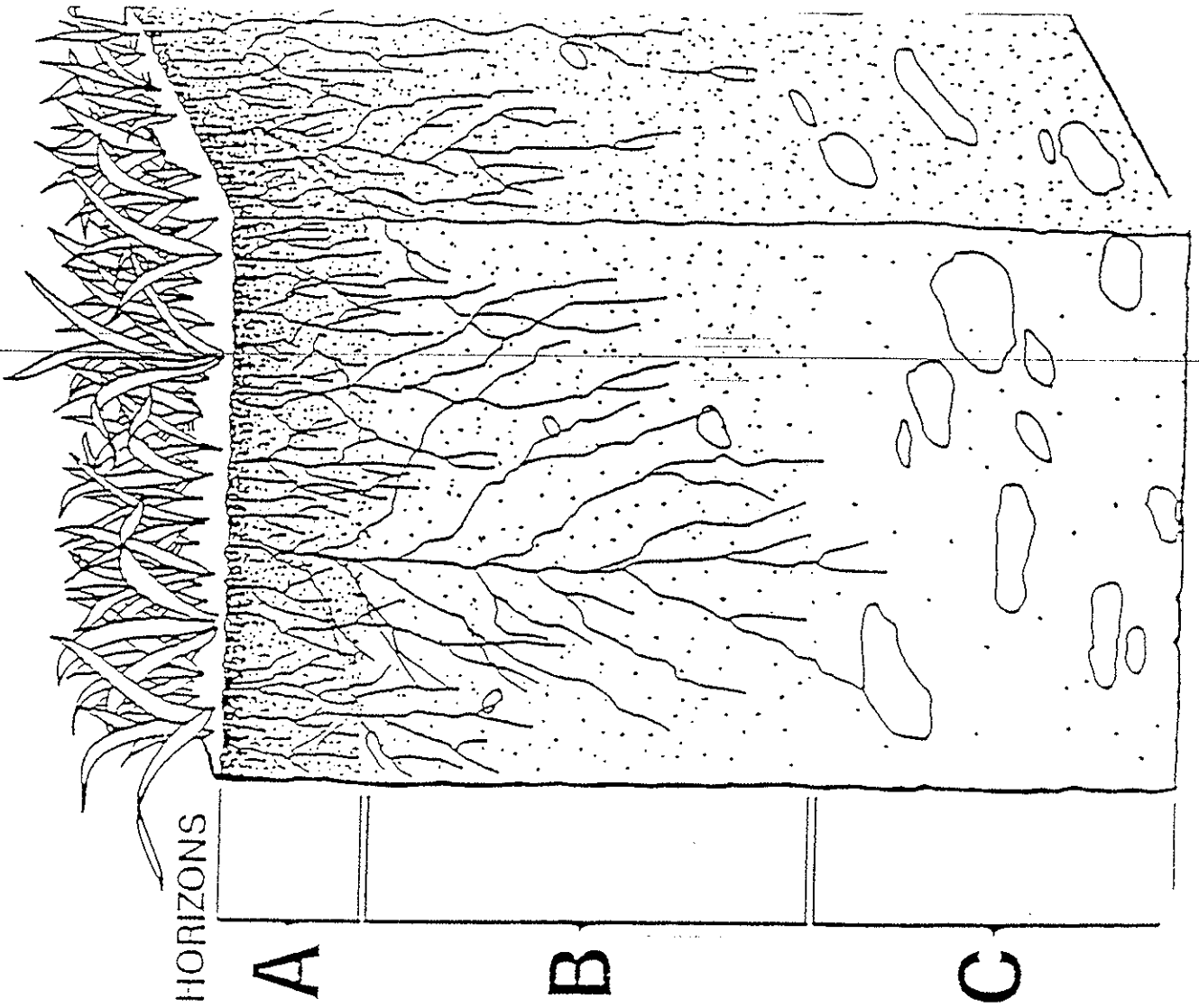
It is the blending of organic materials and mineral particles which really 'makes' soil from rock. Bacteria, fungi, earthworms, rodents, plant roots and plant tops are a few examples of the creatures and agents which add humus and help speed up the breakdown of rock particles. Also, the kinds of plants involved in the cycling of mineral elements, their rooting habits, mineral composition, etc., will play a vital role in the type of soil which eventually develops.

SOIL PROFILE:

If one were to look at a very deep cross-section of *undisturbed* soil, one could see that the upper metre differed from the material below. Being nearer to the atmosphere, this upper zone has been more subject to the action of wind, water and heat, and contains plant and animal residues. It is this upper zone which is commonly known as 'soil' and it is characterized by horizontal layering or 'horizons'. Horizons above the unweathered parent material are collectively referred to as the solum. Every well-developed, undisturbed soil has its own distinctive profile characteristics which are made use of in soil classification and survey and are of great practical importance [see Figure 1:2]. It is not always easy to ascertain the transition from one horizon to another; often it is so gradual that the establishment of boundaries is rather difficult.

The A horizon, commonly referred to as topsoil, is the major zone of root development. It holds most of the nutrients necessary for plant growth, and supplies a large share of the water used by plants. Almost all the soil's organic matter is concentrated here. It is the layer which is plowed and cultivated and is most subject to manipulation. Thus it is generally the focus of discussion when soil management issues are raised.

A SOIL PROFILE



HORIZONS

A

B

C

topsoil
darkest in color
many living things
much organic matter
much plant food

subsoil
lighter in color
fewer living things
less organic matter
little plant food

parent material
rock dust, gravel
no living things
no organic matter
formed as bedrock
breaks

Figure 1:2

MAKE SOME SOIL ARTIFICIALLY

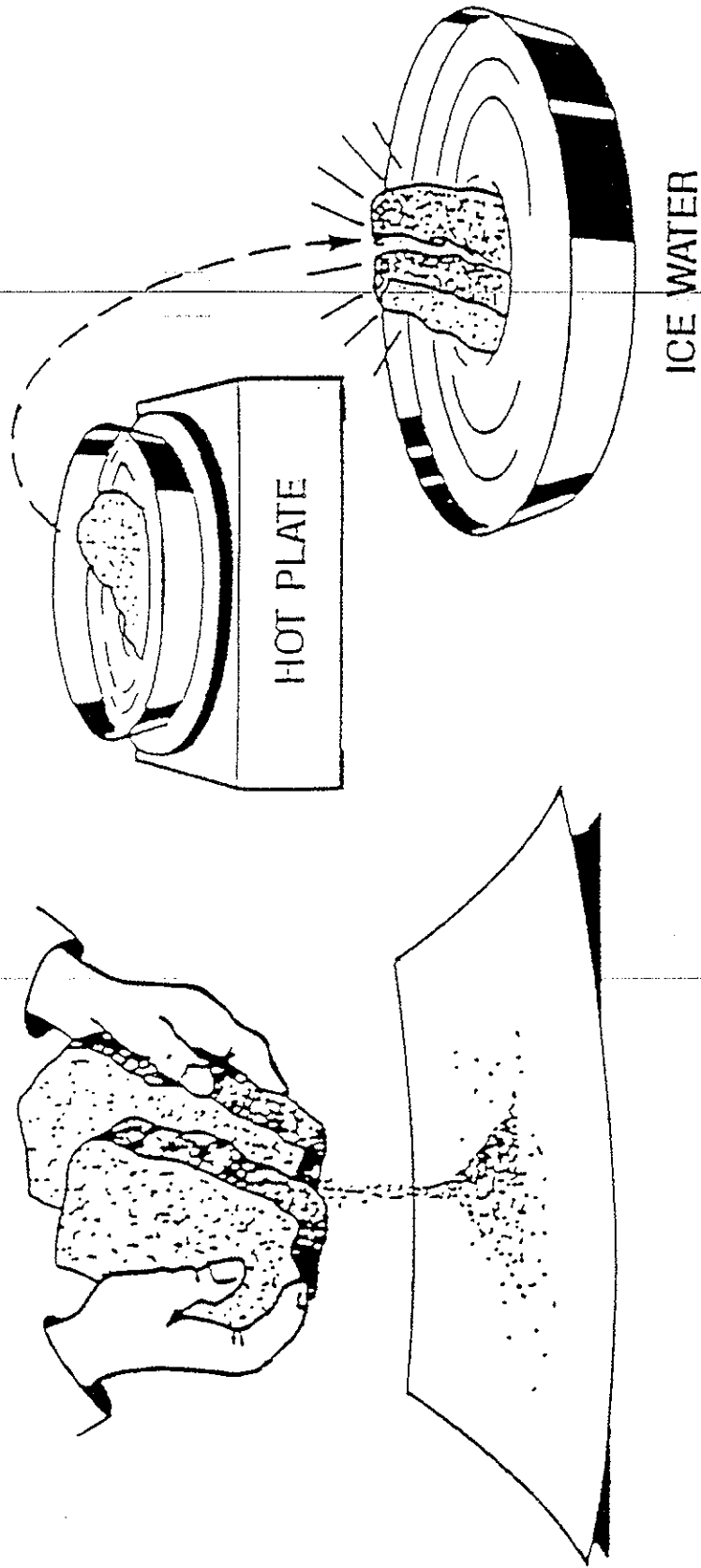


Figure 1:2

ACCELERATED FORMATION OF PARENT MATERIAL

Purpose

To show, by three simple demonstrations, how some of the forces of nature break down rocks into soil material.

Materials

- . 2 pieces of limestone or fine sandstone
- . a hot plate
- . a pan of ice water
- . a small amount of vinegar

Procedures

1. Rub two pieces of limestone or fine sandstone together. Note how long it takes to rub off even a few fine particles.
2. Using tongs and safety glasses, heat a small piece of limestone over a flame or on a hot plate. Drop it quickly into a pan of ice water. Observe the effect of extreme temperature changes on the rock. [It should break or crack as it contracts after its expansion by heating].
3. Put some small pieces of limestone in a little vinegar. Heat the vinegar on a hot plate and notice how bubbles form on the pieces of stone. These bubbles are carbon dioxide gas made from carbon and oxygen released from the limestone by a chemical change in the rock caused by the acid in the vinegar. If you continued this process long enough, all the limestone would gradually break down.

Making Connections

- ✓ How can soil be made from rocks?
- ✓ What is the importance of temperature change?

CHAPTER 2:

PHYSICAL PROPERTIES OF SOILS

Mineral soils consist of four major components:

- mineral matter
- organic matter
- water, and
- air

These components are finely intermixed and often extremely difficult to separate. A topsoil which provides a good growing environment for most plants will ideally be composed of 45% mineral matter, 5% organic matter, 25% water and 25% air [see Figure 2:1]. It must be noted, however, that the proportion of air and water is subject to tremendous fluctuation under natural conditions. Subsoils differ from topsoils as they contain fewer pores for air and water movement and almost no organic matter.

The mineral matter component of soils may be discussed under the headings of soil texture and soil structure.

SOIL TEXTURE

This refers to the degree of fineness or coarseness of the soil. It is determined by the proportion of sand, silt and clay particles present in the soil sample. For example, in some cases larger mineral particles predominate and a gravelly or sandy soil results [see Figure 2:2], while in other cases the mineral colloids [particles of extremely small size] are more prevalent giving the soil clayey characteristics. In almost all soils, all three textural sizes are present to some degree. Thus, mainly gradations between the extremes are found in nature.

Figure 2:3 is a 'textural triangle' — a diagram which can be used for determining the textural class of a soil.

The measurements of sand, silt, and clay particles are: sand - anywhere from 2 mm to 0.05 mm in diameter; silt - between 0.05 mm and 0.002 mm in diameter; and clay - less than 0.002 mm in diameter [and thus too small to be seen without the aid of a powerful microscope].

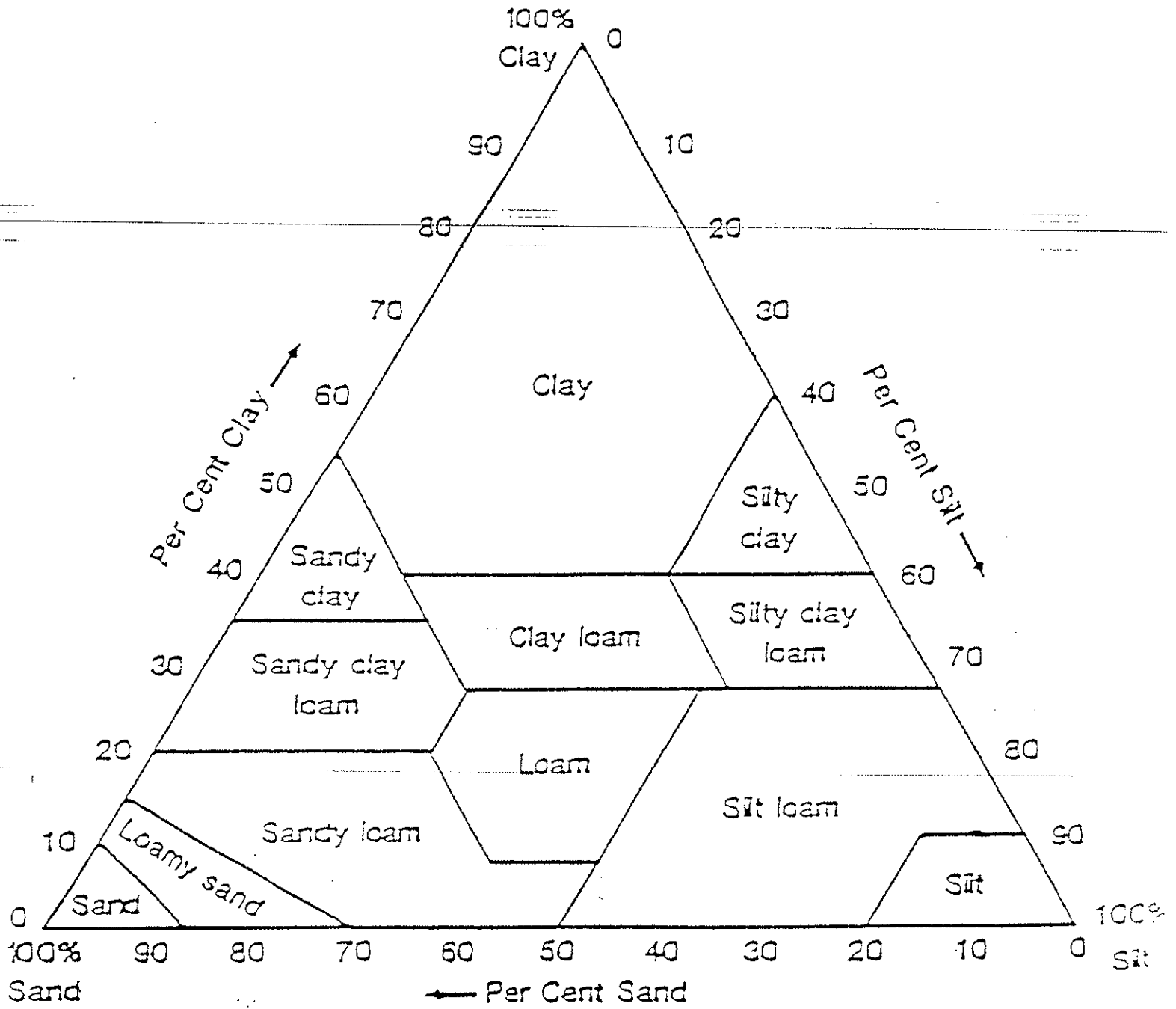
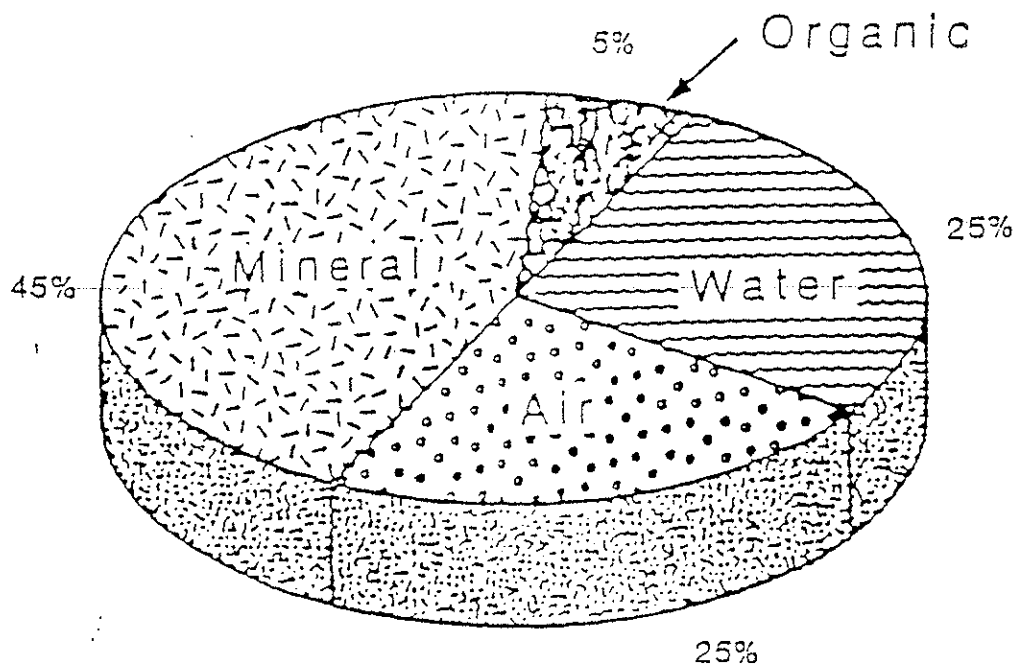


Figure 2:3 Digram by means of which the textural name of a soil may be determined from a mechanical analysis. In using the diagram, the points corresponding to the percentages of silt and clay present in the soil under consideration are located in the silt and clay lines respectively.

COMPOSITION OF SOIL

Soil is composed of mineral matter, organic matter (both living and dead), water and air



Volume composition of a loam soil with optimum aeration conditions for plant growth

Figure 2:1

CROSS-SECTION OF SANDY SOIL - MAGNIFIED

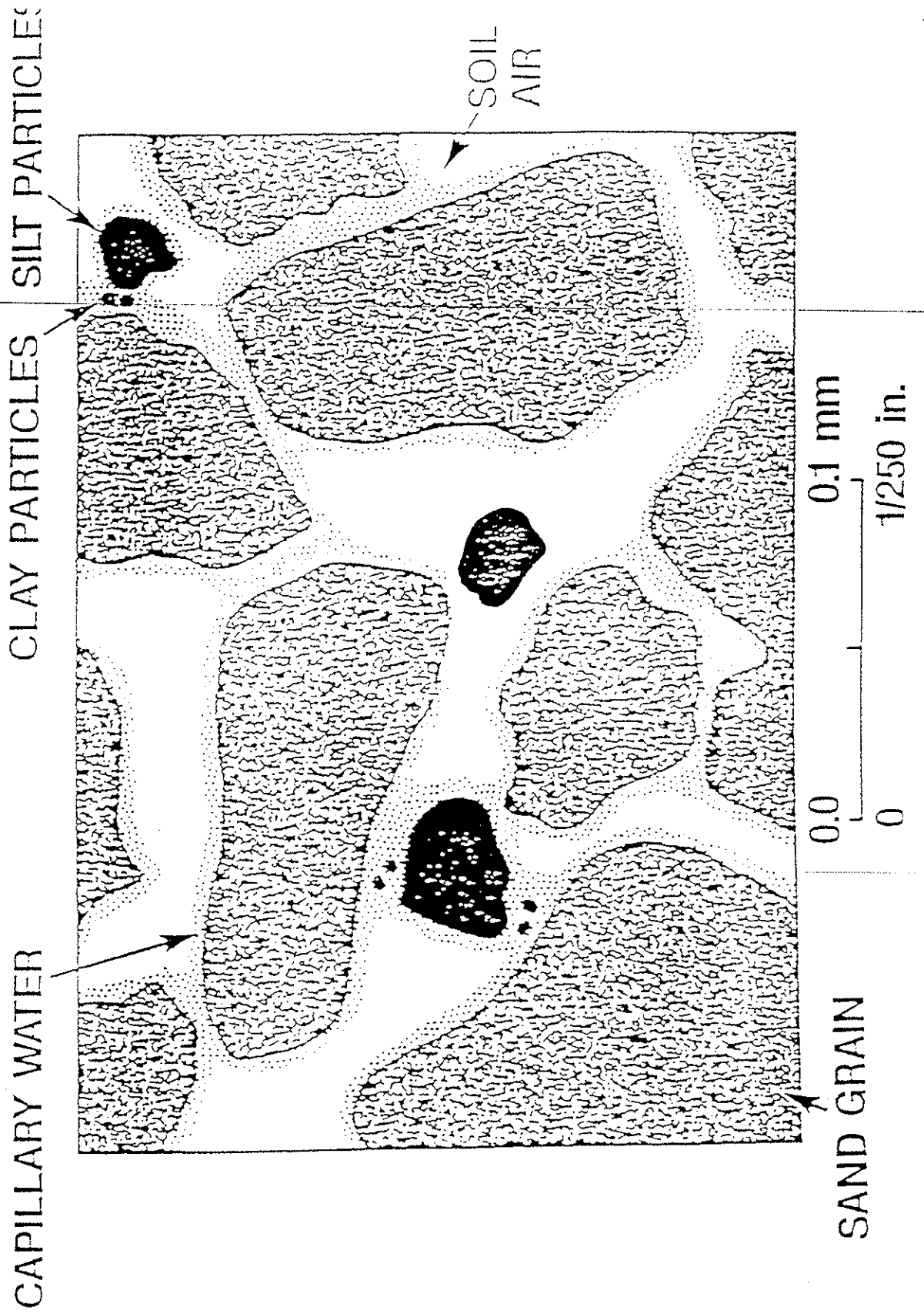
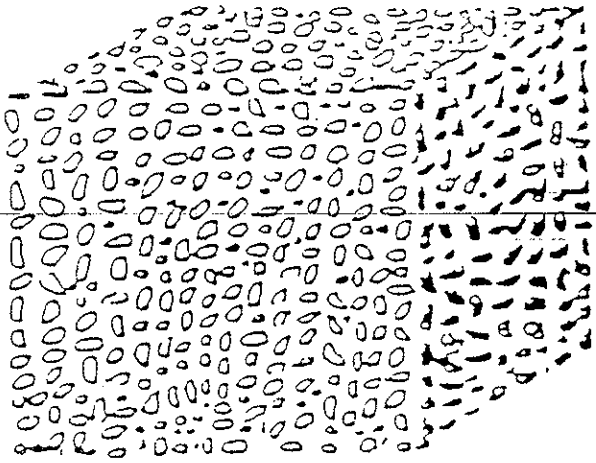
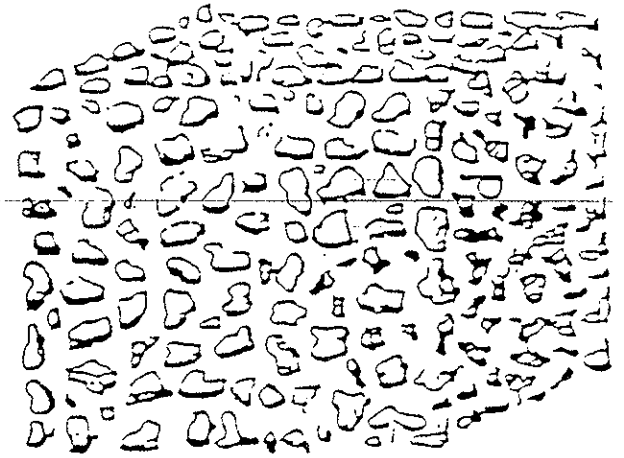


Figure 2:2

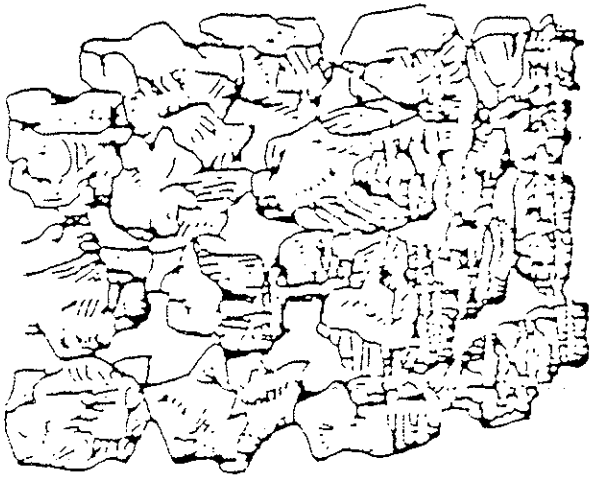
SOIL STRUCTURE



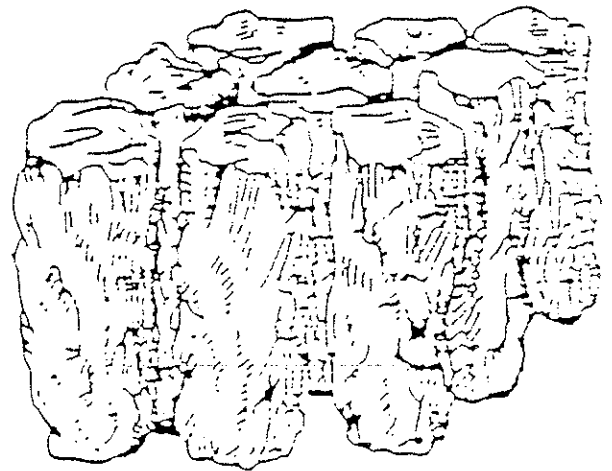
Single grain



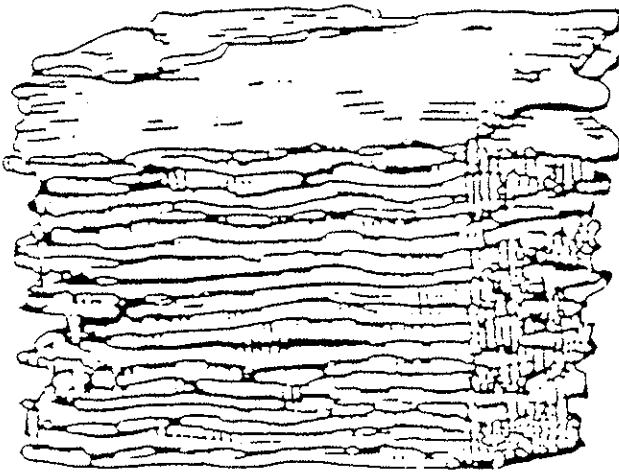
Granular



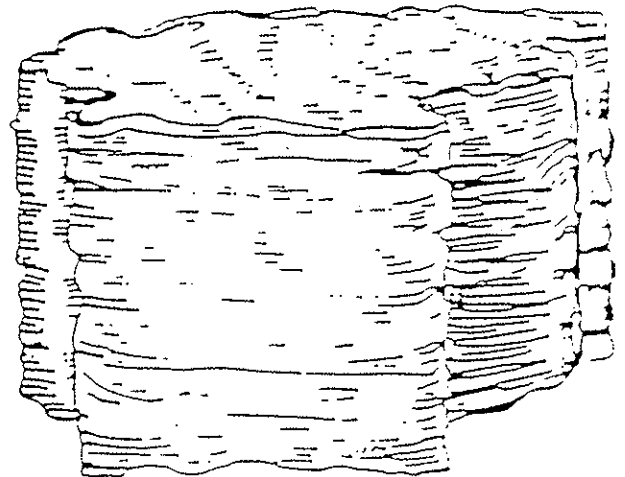
Blocky



Columnar



Platy



Massive

Figure 2:4

ORGANIC MATTER

Soil organic matter can modify some adverse textural characteristics. For example, it allows sands to hold more water while, conversely, in clay soils it improves water drainage by loosening tightly packed clay minerals.

Organic matter is an accumulation of partially decayed and partially resynthesized plant and animal residues. This results from microorganism attack on the stems, leaves, and roots of plant residues and yields a black or brown gelatinous material known as humus. Several factors influence the decomposition process:

- pH - generally values around 7 or neutral favour decomposition by bacteria;
- aeration - with limited oxygen, decomposition is slower and smellier;
- temperature - decomposition is faster at higher temperatures;
- moisture - a minimal amount of available water in a soil is required for the growth of microorganisms; and
- composition and state of the organic residue - fresh succulent plant material will decompose much more readily than older, more mature tissues. Also, small particles provide more surface area for attack by organisms.

Organic matter is a major natural source of three essential plant nutrients; its porous, spongy structure increases the water-holding capacity of soils; and it is the source of energy for microorganisms [Figure 2:5].

The organic matter content may be increased by:

- 1) *green-manuring* - the plowing under of crops when they are in a succulent stage;
- 2) *adding farm manure* - applying animal manure on the land;
- 3) *composting* - the building up of plant materials, soil, and animal by-products by layers and letting them decompose and resynthesize into humus [mainly employed by gardeners];
- 4) *returning stubble and root residues of current crops*.

Organic matter levels can be reduced when tillage brings subsoil up to the surface, when erosion moves topsoil down the field, and when soil is continuously cropped with no return of organic matter.

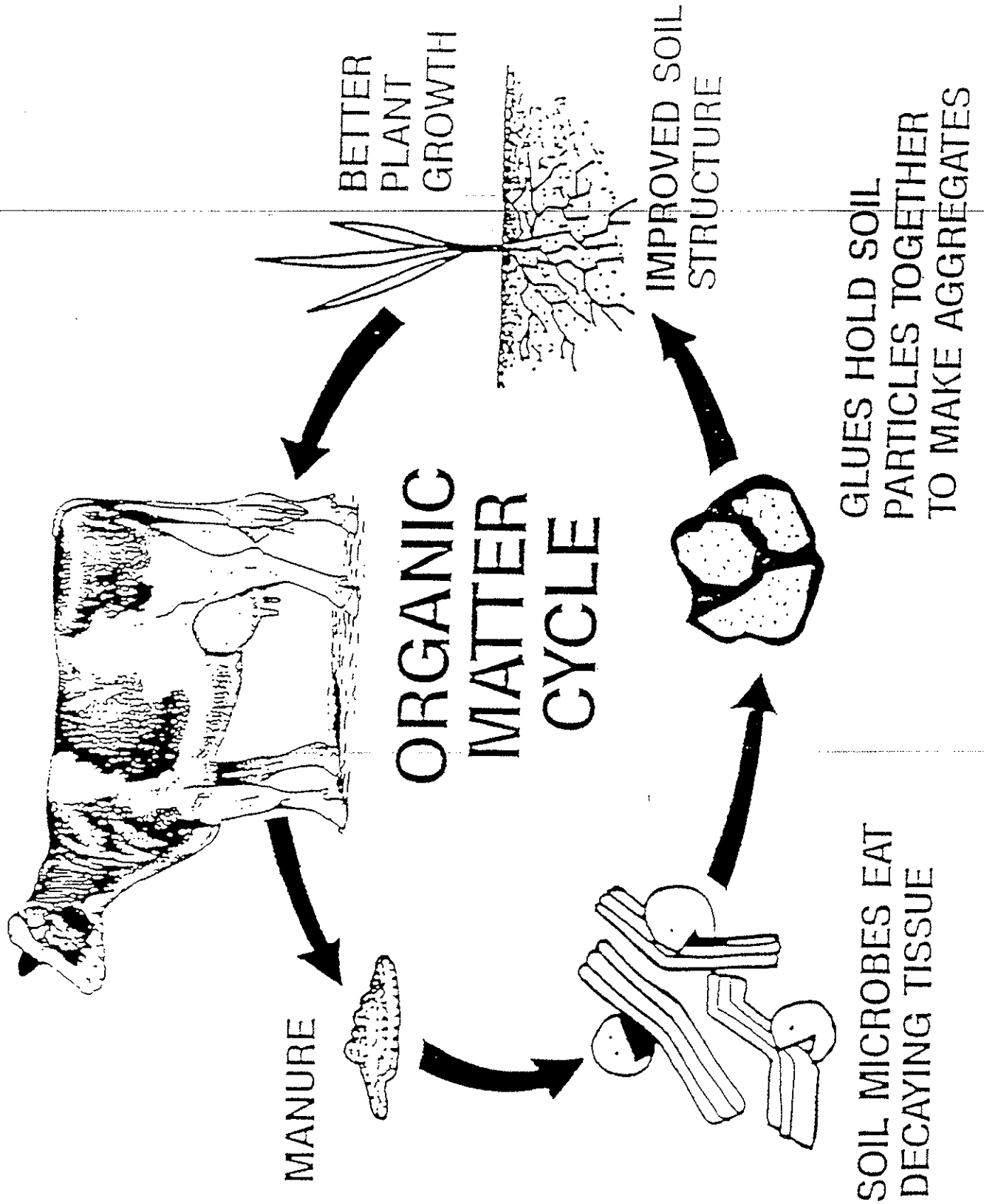


Figure 2:5

SOIL WATER

The process of water entering the soil is called infiltration. The infiltration rate depends on both surface and subsurface conditions. Downward movement of water, once it is in the soil, is called percolation, and is gravity-dependent. Gravity-moved water is abundant in a saturated soil. But water moves within the soil most commonly in an unsaturated condition through the small pores while the larger pores remain filled with air. This is called capillary movement, and it is essentially independent of the force of gravity. It is a function of water film adjustment, which means that water moves in any direction from areas of thick water films around solid particles to areas in which the films are thinner.

Soil contains two types of water: that which is unavailable to plants and that which is available. Soil water may be unavailable under two circumstances: 1) when there is rapid percolation of rainwater through large pores, it might bypass the roots; and 2) when water is present only in thin films that are held too tightly on the surfaces of soil particles for plant roots to extract it. [The wilting point has been reached when this is the only water left in the soil.] The soil water that is available is that which is left after the fast-moving gravitational water has drained away and moisture occurs as films around the mineral and organic particles and in capillary pores that hold the moisture against gravitational pull. Loamy soils which have a good mixture of soil particle size have more available water than sandy soils [which let water drain on through] and clay soils [which hold water films tightly]. Soil water, together with its dissolved salts, makes up the soil solution which is an important medium for supplying nutrients to growing plants.

SOIL AIR

The content and composition of soil air is determined, to a large degree, by the relationship between soil and water. As it is a mixture of gases, soil air moves into those soil pores not occupied by water. Following a rain, the pores first emptied of water are the large ones. As water is removed by evaporation and plant utilization, medium-sized pores are emptied. The relative distribution of large and small pores is an important soil characteristic called soil porosity.

As well as having sufficient pore space there must also be a renewal of the supply of oxygen through adequate air exchange. The growth patterns of plants and roots are adversely affected by poor soil aeration, as is the absorption of nutrients by the plants.

SOIL TEMPERATURE

The soil surface has the greatest variability in temperature, as it receives sunlight during the day and loses heat by radiation at night. Temperature extremes can be moderated by a foliage cover and by mulches, which are layers of material spread over the soil surface. Other variables affecting soil temperature are the colour of the soil - black soils absorb more sunlight than light-coloured soils - and position - soils on a north slope are cooler because solar radiation does not strike them as directly. Soil temperature is important to germination of seeds and plant growth. In humid temperate regions, a wet soil is cold in the spring, which means that seed germination in them is lower than in drier soils. Therefore, by removing excess water through tile-draining, farmers can ensure a good start for crop growth.

SOIL COLOUR

Soil colour has an effect upon the amount of absorption of solar radiation, and is often determined by the type of parent material. A second factor affecting colour is the amount of dark brown humus in the soil. The third colouring agent, iron, is an important indicator of natural drainage conditions: well-drained or dry soils are brown in colour; soils with varying water levels have rust spots or "mottles"; and when the soils are constantly wet, the iron undergoes chemical reduction and is leached out. In these cases the soils will be mainly grey.

SEPARATION OF SOIL COMPONENTS

Purpose

To determine the percentage of water, of organic matter and of mineral matter in some types of soils.

Materials

- . 3 crucibles
- . 3 clay triangles
- . retort stands
- . Bunsen burners
- . balances
- . small quantity of sand, of heavy clay soil, and of a medium soil high in humus

Procedure

1. Weigh an empty crucible and record.
2. Fill the crucible 1/2 to 3/4 full with sand and weigh again.
3. Determine the weight of soil.
4. Place on a retort stand and heat gently for 20-30 minutes to drive off the water in the soil. Stir frequently.
5. Weigh again and determine the weight of water that had been present in the sample.
6. Place the sample back on the retort stand and heat strongly to burn off organic matter. Stir occasionally.
7. Weigh again and determine the weight of organic matter which has been burned out.
8. Note the weight of mineral matter left.
9. Determine the percentage of water, organic matter, and mineral matter in the sample.
10. Repeat using the other two types of soil.

Making Connections

- ✓ What is the weight of the soil?
- ✓ How much water is lost due to heating?
- ✓ How much organic matter was lost due to heating?
- ✓ How much mineral matter was left in the crucible?
- ✓ What is the percent of water lost? organic matter?
- ✓ What is the percent of mineral matter?
- ✓ How much air was in this soil sample?

PARTICLE SIZE

Purpose

To show that soil is composed of various sizes of particles.

Materials

- . 3 tall beakers
- . 3 evaporating dishes
- . a stereoscope or magnifying glass
- . a small quantity of finely ground soil with a very small amount of Calgon mixed in.

Procedure

1. Place about 2 cm of soil in a beaker.
2. Nearly fill the beaker with water.
3. Agitate so that particles are distributed top to bottom.
4. Let the contents settle for 40 seconds.
5. Pour off into a second beaker that which has not settled to the bottom.
6. Let the contents of the second beaker settle for 8-hours.
7. Pour off into a third beaker that which has still not settled to the bottom.
8. Place small samples of the soil and water left in the beakers in separate evaporating dishes and heat gently until they are dry.
9. Examine each sample with a stereoscope or a magnifying glass and compare the size of particles in each.

Making Connections

- ✓ Why do the particles not settle out at the same time?
- ✓ Why are some of the soil particles suspended in the water?
- ✓ Why does the second beaker of soil water take a long time to settle?
- ✓ How do the soil particles of the 3 beakers compare as to size appearance and texture?
- ✓ What kind of soil is found in each of the beakers?
- ✓ What kind of soil has the best porosity? poorest porosity? Why?

HAND-TEXTURING TESTS

Purpose

To determine soil textures by hand.

Materials

. Different types of soil.

Procedure

A) Feel Tests:

Graininess Test-

Soil is rapidly rubbed between thumb and fingers to assess the % sand. Sand particles feel grainy.

Dry Feel Test -

For soils with greater than 50% sand. Soil is rubbed in the palm of the hand to dry it and to separate and estimate the size of the individual sand particles. The sand particles are then allowed to fall out of the hand and the amount of finer material [silt and clay] remaining is noted.

Stickiness Test-

Soil is wetted and compressed between the thumb and forefinger. Degree of stickiness is determined by noting how strongly it adheres to the thumb and forefinger upon release of pressure and how much it stretches. Clay particles lend the stickiness to the soil.

B) Moist Cast Test:

Compress some moist soil by clenching it in your hand. If the soil holds together (ie. forms a cast) then test the strength of the cast by tossing it from hand to hand. The more durable it is, the more clay is present.

C) Ribbon Test:

Moist soil is rolled into a cigarette shape and then squeezed out between the thumb and forefinger to form the longest and thinnest ribbon possible. Soils with a high silt content will form flakes or peel-like thumb imprints rather than a ribbon.

D) Shine Test:

Small amount of moderately dry soil is rolled into a ball and rubbed once or twice against a hard, smooth object such as a knife blade or thumb nail. A shine on the ball indicates at least 35% clay in the soil.

PARTICLE SIZE

Purpose

To show that soil is composed of various sizes of particles.

Materials

- . 3 tall beakers
- . 3 evaporating dishes
- . a stereoscope or magnifying glass
- . a small quantity of finely ground soil with a very small amount of Calgon mixed in.

Procedure

1. Place about 2 cm of soil in a beaker.
2. Nearly fill the beaker with water.
3. Agitate so that particles are distributed top to bottom.
4. Let the contents settle for 40 seconds.
5. Pour off into a second beaker that which has not settled to the bottom.
6. Let the contents of the second beaker settle for 8 hours.
7. Pour off into a third beaker that which has still not settled to the bottom.
8. Place small samples of the soil and water left in the beakers in separate evaporating dishes and heat gently until they are dry.
9. Examine each sample with a stereoscope or a magnifying glass and compare the size of particles in each.

Making Connections

- ✓ Why do the particles not settle out at the same time?
- ✓ Why are some of the soil particles suspended in the water?
- ✓ Why does the second beaker of soil water take a long time to settle?
- ✓ How do the soil particles of the 3 beakers compare as to size appearance and texture?
- ✓ What kind of soil is found in each of the beakers?
- ✓ What kind of soil has the best porosity? poorest porosity? Why?

HAND-TEXTURING TESTS

Purpose

To determine soil textures by hand.

Materials

. Different types of soil.

Procedure

A) Feel Tests:

Graininess Test-

Soil is rapidly rubbed between thumb and fingers to assess the % sand. Sand particles feel grainy.

Dry Feel Test -

For soils with greater than 50% sand. Soil is rubbed in the palm of the hand to dry it and to separate and estimate the size of the individual sand particles. The sand particles are then allowed to fall out of the hand and the amount of finer material [silt and clay] remaining is noted.

Stickiness Test-

Soil is wetted and compressed between the thumb and forefinger. Degree of stickiness is determined by noting how strongly it adheres to the thumb and forefinger upon release of pressure and how much it stretches. Clay particles lend the stickiness to the soil.

B) Moist Cast Test:

Compress some moist soil by clenching it in your hand. If the soil holds together (ie. forms a cast) then test the strength of the cast by tossing it from hand to hand. The more durable it is, the more clay is present.

C) Ribbon Test:

Moist soil is rolled into a cigarette shape and then squeezed out between the thumb and forefinger to form the longest and thinnest ribbon possible. Soils with a high silt content will form flakes or peel-like thumb imprints rather than a ribbon.

D) Shine Test:

Small amount of moderately dry soil is rolled into a ball and rubbed once or twice against a hard, smooth object such as a knife blade or thumb nail. A shine on the ball indicates at least 35% clay in the soil.

CAPILLARY WATER

Purpose

To see how capillary water moves through coarse, medium and fine soil particles.

Materials

- . 3 glass or plastic cylinders - (plastic cylinders can be made by rolling up an overhead acetate and taping along its length with waterproof tape)
- . 3 small pans or low wide-mouthed glass jars
- . some thin cloth some
- . string or rubber bands
- . sample of sand, clay, and good loamy garden soil.

Procedure

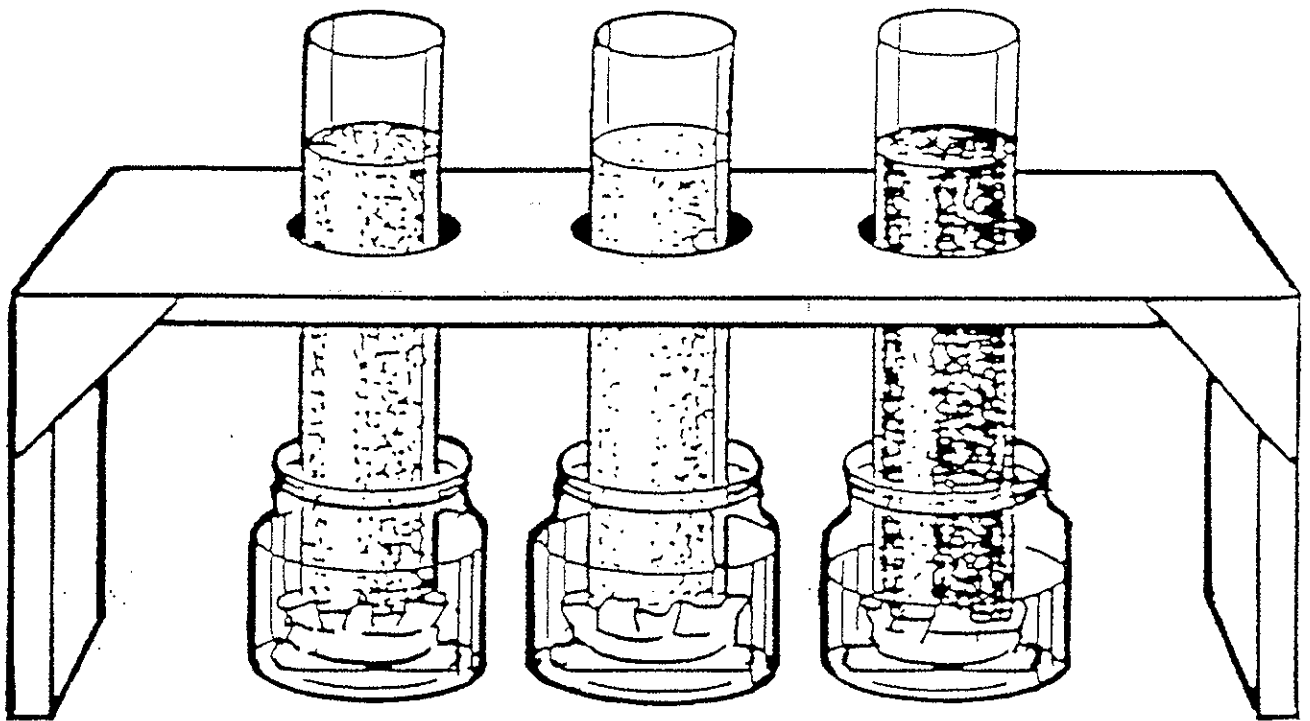
1. Fasten the cloth over the top of the cylinders.
2. Turn them upside down and fill each three-fourths full with one of the dry soils (the clay soil is sticky when wet but dries in hard clods - grind up the clods and put the dry clay in the cylinder). Bump the cylinder slightly on a table to settle the soil.
3. Set the cylinders in the jars and pour water in the jars - do not pour water in the cylinders.
4. Observe the height to which the water has risen in each tube after 30 minutes and record.
5. Let apparatus sit for a few days and note and record daily the water level in each column.

Making Connections

- ✓ How far did the water move in each of the cylinders?
- ✓ How fast did the water move in each of the cylinders?
- ✓ Why did the water move the fastest in the sand?

[If the spaces around the soil particles are large, the attraction between the water molecules and the soil particles will not be enough to overcome the weight of the water and it will not rise appreciably; however, what movement it makes will be rapid because there will be little friction.]

SEE HOW CAPILLARY WATER MOVES THROUGH SOIL



ORGANIC MATTER HELPS SOIL STRUCTURE

Purpose

To demonstrate that organic matter in the soil promotes the maintenance of good soil structure.

Materials

- . 2 wide mouth jars
- . 2 small baskets made out of wire mesh [these can be made by bending the wire so it will extend like a basket down into the jars
- . lumps of soil (not sandy) - these can be collected from:
 - a natural sod fence row, backyard or park, and
 - a cultivated field that has been farmed heavily and where soil is light in colour. Lumps should be about twice the size of an egg.

Procedure

1. Fill the jars with water within 2 cm of the top. Place the lumps of soil in the baskets and lower into the jars. Watch closely and record what happens.

Making Connections

- ✓ Why did the soil from the heavily cultivated field fall apart?
- ✓ What makes the other soil sample cling together?
- ✓ Which soil would be easier to cultivate?
- ✓ Which soil will water break down more easily?

WATER/AIR RELATIONSHIPS

Purpose

To demonstrate how water/air relationship affects growing plants. [This will likely take from 6-8 weeks.]

Materials

- 2 similar plants in flower pots with similar soils; [i.e. bean plant]-
 - please don't choose marsh plants or plants which aren't expendable.

Procedure

1. Start a different watering regime in each of the two pots. In one, water thoroughly until water appears in the dish, then leave enough time between waterings so that the soil surface becomes dry. Water the other plant sufficiently so that water is constantly standing in the dish.

Making Connections

- ✓ What is the difference in the plant tops?
- ✓ What is the difference in the plant roots?

HUMUS AND WATER HOLDING CAPACITY

Purpose

To show the effect of humus on the water holding capacity of soils.

Materials

- . 2 glass or plastic tubes about 3-4 cm in diameter, 35-50 cm long and open at both ends
- . 2 beakers
- . 2 graduated cylinders,
- . 2 retort stands
- . a quantity of dry sand, and a quantity of dry peat moss
- . 2 pieces of cloth approximately 15 cm square.

Procedure

1. Tie a piece of cloth over one end of both tubes.
2. Fill one tube about 3/4 full of sand.
3. Support the tube on a retort stand in an upright position.
4. Place a beaker underneath the tube.
5. Repeat with the second tube using equal amounts of sand and peat moss that have been thoroughly mixed.
6. Pour equal amounts (~ 75 ml) of water into the top of each tube.
7. After 20 minutes, pour the water that has collected in the beakers into the graduated cylinders and compare the amounts.

Making Connections

- ✓ Which of the two beakers had less water?
- ✓ Which column of soil held more water?
- ✓ What is the effect of humus on the soil's water holding capacity?
- ✓ What kind of soils will hold more water?
- ✓ Which soil has the best drainage?

WATER HOLDING CAPACITY OF SOILS

Purpose

To measure the water holding capacity of soils

Materials

- . 3 - 284 mL soup cans [both ends removed]
- . 3 squares of cheesecloth each 15 cm x 15 cm
- . 3 plates to cover bottom of soup cans
- . 6 elastic bands
- . 275 mL each of thoroughly dry, crumbled clay, sand, and loam
- . 100 mL graduated cylinder
- . margarine tub
- . ruler

Procedure

1. Firmly attach, with elastic bands, three layers of cheesecloth to one end only of each can. Place the cheesecloth end of each can on a separate plate.
2. Fill one of the cans to within 2 cm of the top with dry clay, the second can with dry sand, and the third can with dry loam.
3. Record the volume of soil added to each can.
4. Obtain three containers to catch water which drains through the cans.
5. Holding the can with clay firmly against the plate, add water to the clay to the point of saturation [water rests on the surface].
6. Gently tap each can to remove air [all of the spaces between the particles of soil should by now be filled with water].
7. Record the volume of water added. Holding the can over a container, remove the plate and allow water to drain away.
8. Record the volume of water which drained away.
9. Repeat the same procedure for the sand sample and then for the loam sample.
10. Calculate the water holding capacity of each soil:

(volume of water) - (volume of water drained) = volume of water remaining.

Water holding capacity = $\frac{\text{volume of water remaining} \times 100\%}{\text{volume of soil}}$

Making Connections

- ✓ How would the addition of various types of soil particles alter the water holding capacity of any given soil?

HOW DO SOILS DIFFER?

Purpose

To assess the physical characteristics of a soil sample.

Materials

Soil sample or samples

Procedure

- By using the following charts, answer the discussion questions below about the soil sample.

Chart 1

Soil Type by Texture	Feel When Wet	Looseness of Soil	Water-Holding Capacity	Aeration
Clayey	Very sticky, smooth, slick	Poor	High [water is held so tightly that less is available for plants]	Low
Sandy	Very gritty	Loose, crumbly	Poor	High
Loamy	Smooth and slick, somewhat gritty and sticky	Loose, crumbly	Good to excellent	High

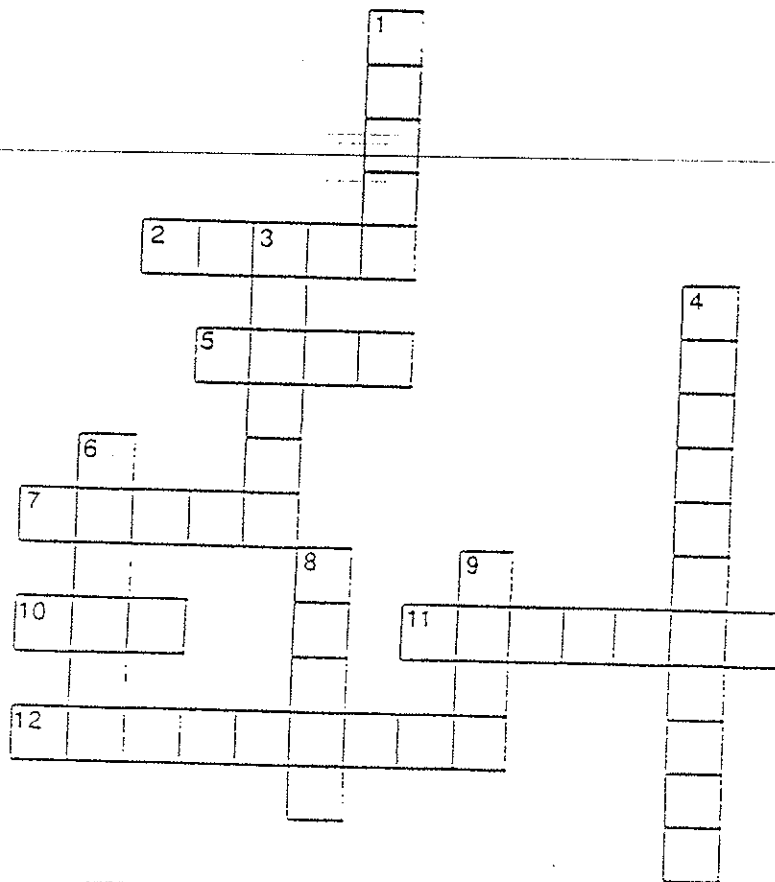
Chart 2

Soil Type by Colour	Organic Content	Fertility	Aeration
Dark Soils	High	High	High
Moderately Dark Soils	Medium	Medium	Medium
Light-Coloured Soils	Low	Low	Low

Making Connections

- ✓ What is the colour of your soil sample?
- ✓ What is the texture of your soil sample?
- ✓ Would you buy a farm with this type of soil on most of the fields? Why?
- ✓ Why are pore spaces so important in soils?
- ✓ Why is it important for soil to have good drainage?
- ✓ Describe the perfect physical traits of soil for a garden - [dark colour, loamy texture]

CROSSWORD - CHAPTERS 1 AND 2



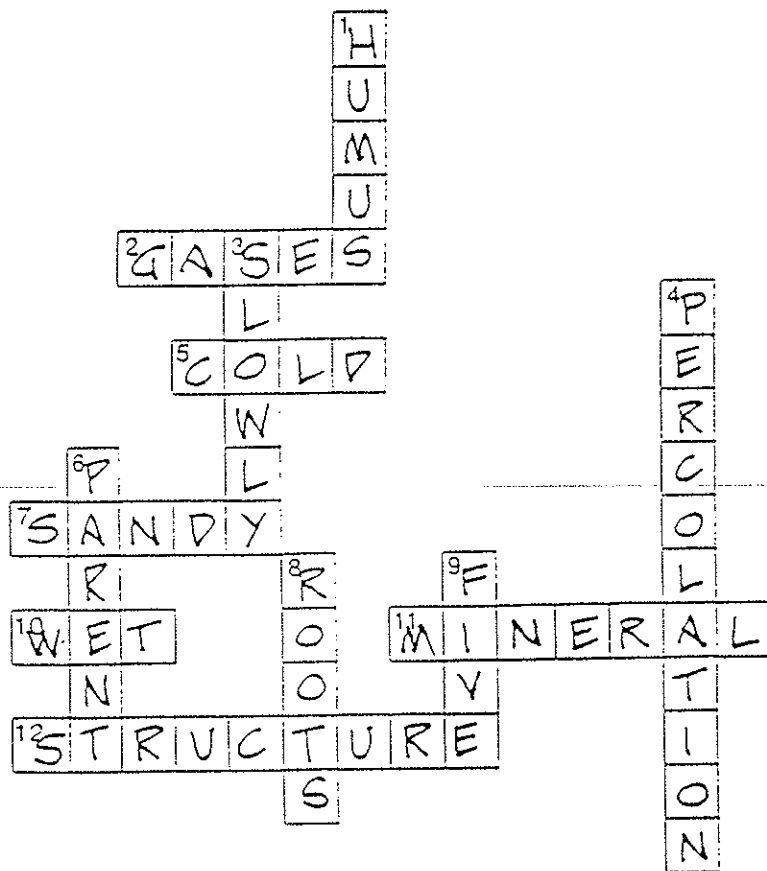
ACROSS

- 2 Soil air is a mixture of _____.
- 5 In the spring, wet soil is _____.
- 7 If coarse grains are visible in the soil, it is classified as _____.
- 10 Grey colour in soils indicates that they are _____.
- 11 Chemical weathering of rocks produces _____ soil particles.
- 12 Soil _____ is the arrangement of soil particles.

DOWN

- 1 Micro-organisms attack plant and animal residues and form a dark, rich material called _____.
- 3 Soil is formed very _____.
- 4 Within the soil, downward movement of water is called _____.
- 6 The _____ material is the material from which soil is formed.
- 8 Most of the water entering a plant comes through its _____.
- 9 Soil formation is a function _____ factors.

ANSWERS TO CROSSWORD - CHAPTERS 1 AND 2



CHAPTER 3:

SOIL FERTILITY

Sixteen nutrient elements have been shown to be essential for plant growth. Table 3:1 lists the elements according to sources - whether primarily from air and water or from soil solids - and according to amount used by plants.

TABLE 3:1

ESSENTIAL NUTRIENT ELEMENTS AND THEIR SOURCES

Elements Used in Relatively Large Amounts	Elements Used in Relatively Small Amounts
<p><u>Mostly from air and water:</u></p> <ul style="list-style-type: none"> • Carbon } From the air • Oxygen } • Hydrogen } From the water <p><u>From soil minerals and organic matter:</u></p> <ul style="list-style-type: none"> • Nitrogen • Calcium • Phosphorus • Magnesium • Potassium • Sulphur 	<p><u>From soil minerals and organic matter:</u></p> <ul style="list-style-type: none"> • Iron • Copper • Manganese • Zinc • Boron • Chlorine • Molybdenum

It is usually the nutrient elements obtained from the soil that limit crop development. Plant growth, except in cases of drought, cold weather, poor drainage or disease, is not seriously retarded by a lack of carbon, hydrogen or oxygen.

Of the thirteen essential elements obtained from the soil, six are used in relatively large quantities and are called macronutrients. As may be seen from Table 3:1, they are: nitrogen, phosphorus, potassium, calcium, magnesium and sulphur.

Nitrogen, phosphorus and potassium are commonly supplied to the soil by farm manure and commercial fertilizers and are called the fertilizer elements. On a bag of commercial fertilizer, the notation of 6-24-24 [for example] indicates the percent by weight of nitrogen (N), phosphorus (P), and potassium (K) compounds respectively. Calcium and magnesium are applied as lime and thus are lime elements. Sulphur is supplied by rain water and is also an incidental ingredient of manure and commercial fertilizer.

Nitrogen: Nitrogen is a major component of protein in plants and therefore is important for crop quality. It stimulates growth and gives leaves their dark green colour. It is also needed by soil microorganisms for organic matter decomposition. A deficiency of available nitrogen in the soil probably limits plant growth more often than any other nutrient. The nitrogen cycle is: atmospheric nitrogen is fixed in the soil by special bacteria and some plant roots - it is then taken up by the plants - through the decomposition of plants, it returns back to the soil and to the air. There is a family of plants called legumes, e.g. clover, alfalfa, peas, which have nitrogen-fixing bacteria in their root tissue and thus are invaluable for supplying nitrogen to the soil.

Phosphorus: Phosphorus promotes rapid and vigorous growth in plants and also is important in root and seed development. P in soils and plants usually occurs in combination with other elements including oxygen, in which case it is referred to as phosphate.

Potassium: Potassium is responsible for improving plant resistance to disease. It builds vigour and strength in plants.

Calcium: When these elements are lacking, the soils tend to be acid. The acidity or alkalinity of soil can be measured in pH units. It ranges on a scale from 1 to 14, and
Magnesium with a pH of 7 being neutral. An acid soil has a pH below 7.0 and an alkaline soil has a pH above 7.0. If the pH is too high or low, it may prevent the plants from taking up some of the soil's nutrients. Crop plants grow best in a pH range of 6.5 to 7.5.

Sulphur: Sulphur is an important constituent of enzymatic and structural proteins. Usually there is not a deficiency of sulphur in Ontario soils [in part due to acid rain].

Micronutrients:

Micronutrients are used by plants in very small amounts though they are fundamentally just as important as macronutrients. Micronutrients [or, as they are sometimes called, "trace elements"] are iron, manganese, copper, zinc, boron, molybdenum and chlorine. Their availability is sometimes quite low, especially in alkaline soils. On the other hand, in very acidic soils their availability may be so great that they are toxic to plants.

Plants absorb nutrients largely from the soil solution. As the soil solution moves to the root to supply the plant with water, ions are carried along with it to the root surface where they may be absorbed into the root. Therefore, a prerequisite for ion absorption is the proliferation of roots and root hairs into the soil.

TABLE 3:2

FERTILITY MAINTENANCE

Adequate supply of nitrogen from:	<ul style="list-style-type: none"> • Farm manure • N fertilizers • Crop residues, legumes rain and snow
Addition of phosphorus:	<ul style="list-style-type: none"> • Superphosphate or other fertilizer
Adequate supply of available potassium from:	<ul style="list-style-type: none"> • Farm manure • Crop residues • Potash fertilizers
Addition of organic matter:	<ul style="list-style-type: none"> • Green manure • Crop residues • Farm manure
Addition of lime if necessary:	
Application of trace elements:	<ul style="list-style-type: none"> • As separate salts or in mixture

As may be seen from the above table, fertility of the soil can be maintained by the use of farm manures, green manures, artificial fertilizers, crop residues, legumes, lime, proper tillage and crop rotation. Each separate component of this system is not enough to ensure adequate supplies of plant nutrients. For example, farm manures are high in organic matter, nitrogen, and potassium, but are lacking in phosphorus. Commercial fertilizers do not add organic matter to the soil, and may build up dangerous levels of salts; however, when carefully controlled they can be a good and easy way of adding essential elements which may be lacking in the soil.

FERTILIZER AND PLANT GROWTH

Purpose

To observe the effects of fertilizer on plant growth.

Materials

- . 2 flower pots
- . a mortar and pestle
- . soil of low fertility - may be obtained from an eroded, overworked field, or one can use subsoil;
- . bean seeds
- . N fertilizer [ammonium nitrate]
- . P fertilizer [superphosphate].

Procedure

1. Grind the fertilizer materials in the mortar until they are very fine.
2. Place about .5L of soil on a sheet of paper.
3. Add to this soil one-half as much N fertilizer as can be heaped on a dime. Then add the same amount of P fertilizer.
4. Mix these fertilizers thoroughly with the soil.
5. Fill one pot with fertilized soil and the other with unfertilized soil.
6. Plant a few of the same kind of seeds in each pot and cover with about ½ cm of sand to prevent soil crusting.
7. When the plants are well established, thin them to the same number in each pot. Watch their growth for several weeks, keeping them watered and in some sunshine.

Making Connections

- ✓ Which pot produces the healthiest plants?

SOIL FERTILITY

Purpose

To compare the fertility of soils by growing plants in them.

Materials

- . 3 flowerpots
- . 3 soil samples: 1) topsoil from an old fence row or a well-maintained garden;
 2) soil from an eroded hillside;
 3) subsoil from a depth of 1 m [e.g. from a roadbank]
- . bean seeds

Procedure

1. Fill each of the flowerpots with a different soil sample. Plant a few beans in each pot [soaking the beans overnight in water will hasten germination].
2. Keep the pots watered and place them where they will be warm and have some sunshine.
3. Keep a record of how fast the beans in each pot grow and how each plant looks.

Making Connections

- ✓ Which plants look the healthiest?
- ✓ What problems do some of the plants exhibit?

Branching Out

As an extension to this activity, one can test the soil samples through the soil testing facilities of The Ontario Ministry of Agriculture Food and Rural Affairs. Soil sample boxes and information sheets may be obtained from any local office of Ontario Ministry of Agriculture, Food and Rural Affairs [OMAFRA] or through the testing lab which is Agri-Food Laboratories, 503 Imperial Road, Unit One, Guelph, Ontario N1H 6T9 [1-800-265-7175]. A fee of \$7.00/sample is charged and the test results will indicate the plant-available phosphorus, potassium, magnesium, pH, and lime requirements of the soil sample.

THE pH OF A SOIL

Purpose

To determine the acidity or alkalinity of a soil.

Materials

- Mist samples of as many different soils as possible; forest, pasture, heavily cultivated, bogs, etc;
- pH hydron papers -available from a scientific supply house or garden centre

Procedure

1. Using a moist soil sample, stick a piece of pH paper into the soil. It will turn a certain colour which you can match to the value listed on the colour-coded casing on the pH papers.

Making Connections

- ✓ Do your samples have good pH value for most plants?
- ✓ Discuss differences in pH due to the organic matter content, and the plants that have been growing on the soil.

CHAPTER 4:

SOIL FLORA AND FAUNA

A healthy soil is filled with soil flora [plants] and fauna [animals]. Table 4:1 shows some of the more important groups of organisms that commonly are present in soils.

LIVING ORGANISMS IN THE SOIL		
PLANTS	ANIMALS	
	MACRO	MICRO
Roots Algae Fungi [yeasts, molds, etc] Actinomycetes Bacteria [aerobic, anaerobic]	Small animals - mice, groundhogs, moles, squirrels, etc	Nematodes Protozoa Rotifers
	Insects - ants, grubs, springtails, etc	
	Millipedes	** Predatory or parasitic or living on plant materials
	Centipedes	
	Spiders	
	Mites	
	Slugs and snails	
	Earthworms	
	** predatory or living on plant materials	

Life of the soil may be divided by function:

- those organisms that supply organic residues and
- those that are engaged primarily in tearing such residues down.

In the first group are plant roots: as a source of organic matter, the roots of higher plants supply more original tissue than all of the other organisms combined. Also in the first group, the soil animals contribute at death to the accumulation of decomposable tissue.

A great variety of insects and worms use more or less undecomposed plant and animal tissue as food and therefore serve to initiate the decomposition processes that are continued by bacteria and fungi. The role of bacteria and fungi in the formation of humus has been discussed, as has their role in the supply of nitrogen.

Macroorganisms serve the purposes of aerating the soil, and mixing organic matter with mineral matter. For example, it is estimated that earthworms bring 20-40 tonnes of soil per hectare annually to the surface by burrowing through the soil, consuming organic matter, and depositing their residue on the surface as castings. The digging, digesting and depositing of subsoils is invaluable in keeping a soil loose and healthy.

The number of microorganisms in the soil is much greater than that of macroorganisms. The number of soil microanimals alone in a hectare of soil to a depth of 25 cm can be over 100 billion, and protozoa might amount to a live weight of over 100 kg/ha.

To summarize, some of the activities of soil organisms that are beneficial to plants include:

- organic matter decomposition, in which nutrients are released for use and the stability of soil aggregation is enhanced by humus;
- nitrogen fixation by legume bacteria;
- the production of nitrates and sulfates; and
- soil aeration.

The injurious effects of soil organisms on higher plants include:

- the damage done by slugs, rodents, nematodes, etc., as they chew and disturb plant tissue;
- the contribution to plant disease, e.g. wilts, root rot, etc., by bacteria, fungi and actinomycetes; and
- the competition for nutrients, especially nitrogen, by the soil organisms.

A SOIL ECOSYSTEM

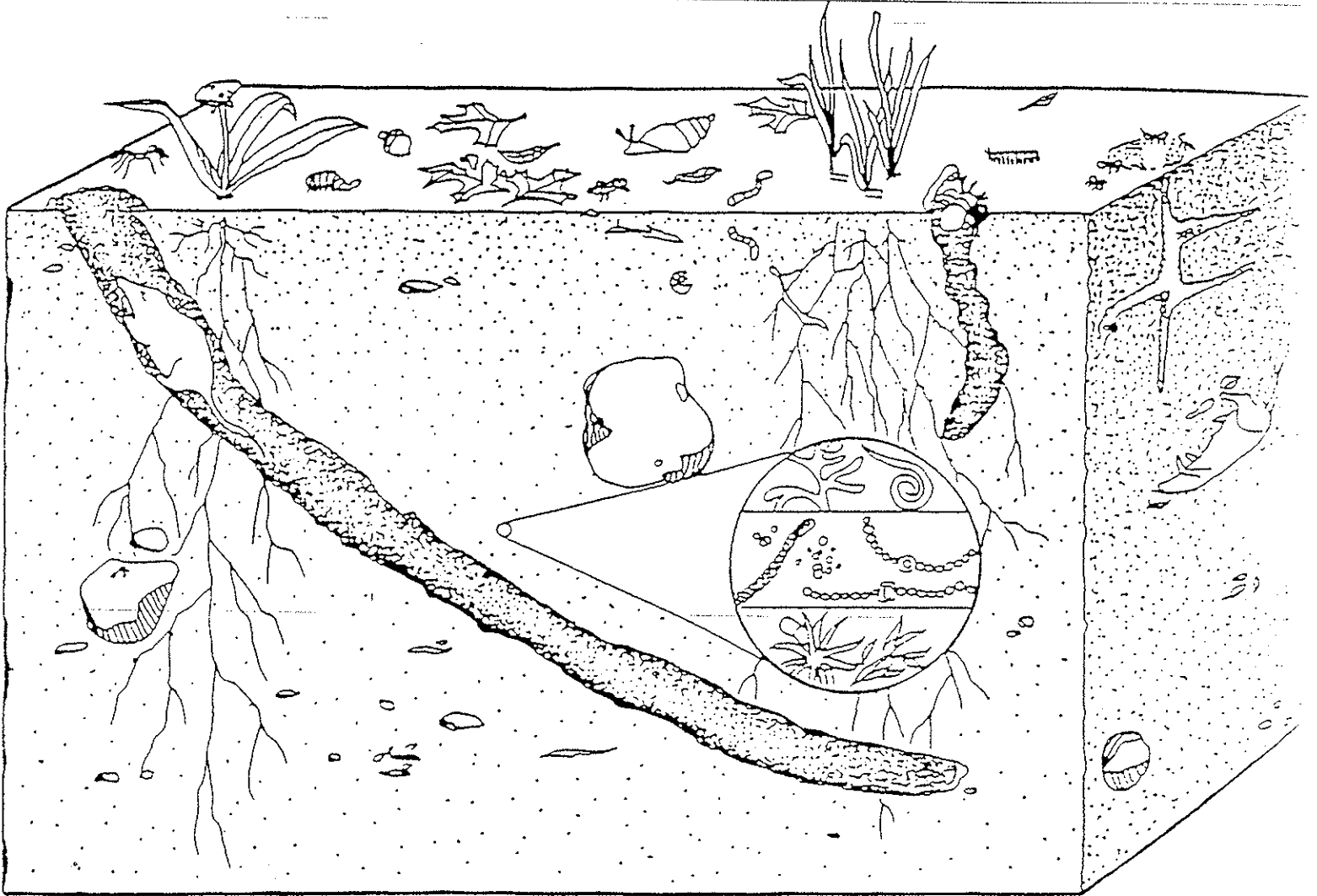


Figure 4:1

SOIL LIFE

Purpose

To discover and observe life in a soil sample.

Materials

- . 3 heavy paper shopping bags
- . ruler
- . small spade;
- . 6 or more bottles with lids or corks;
- . small magnifying glass;
- . 3 soil samples: 1) from below the leaves in a woodlot;
 2) from a pasture or fence row; and
 3) from an eroded field [or subsoil].

Procedure

1. Measure an area 30 cm square and collect the soil to the depth of 6-7 cm from each of the sample areas. As you remove the soil, watch for burrows of worms and other animals. You may also find the eggs of certain insects singly or in masses or pods.
2. Examine the samples, using a microscope if possible.
3. Pour out the samples on separate sheets of white paper the size of an opened newspaper.
4. Carefully sort the soil, watching closely for small living things.
5. Hardware cloth or window screen will be helpful in making this examination.
6. Place the different kinds of animal life in separate bottles.
7. Count the animal life belonging to each of the following groups:
 - 1) worms [such as earthworms or night crawlers having no legs];
 - 2) grubs [any worm-like animal with legs];
 - 3) snails [or slugs];
 - 4) insects [any hard-shelled, soft-bodied, or winged animal with three pairs of legs];
 - 5) spiders, mites, ticks [animals with 4 pairs of legs];
 - 6) animals with more than 4 pairs of legs;
 - 7) others.

Making Connections

- ✓ Which soil sample has the most small animal life?
- ✓ Is this related to any soil component?
- ✓ Does the amount of animal life appear to have any relation to the looseness of the soil?
- ✓ Calculate the total number of animals per hectare for each group from each of the sampled areas.

INVESTIGATING A SOIL COMMUNITY

Purpose

To observe the living components of a specific soil community.

Materials

- . Small trowel
- . a hand lens or magnifying glass
- . a piece of white paper
- . plastic bag(s) for soil samples

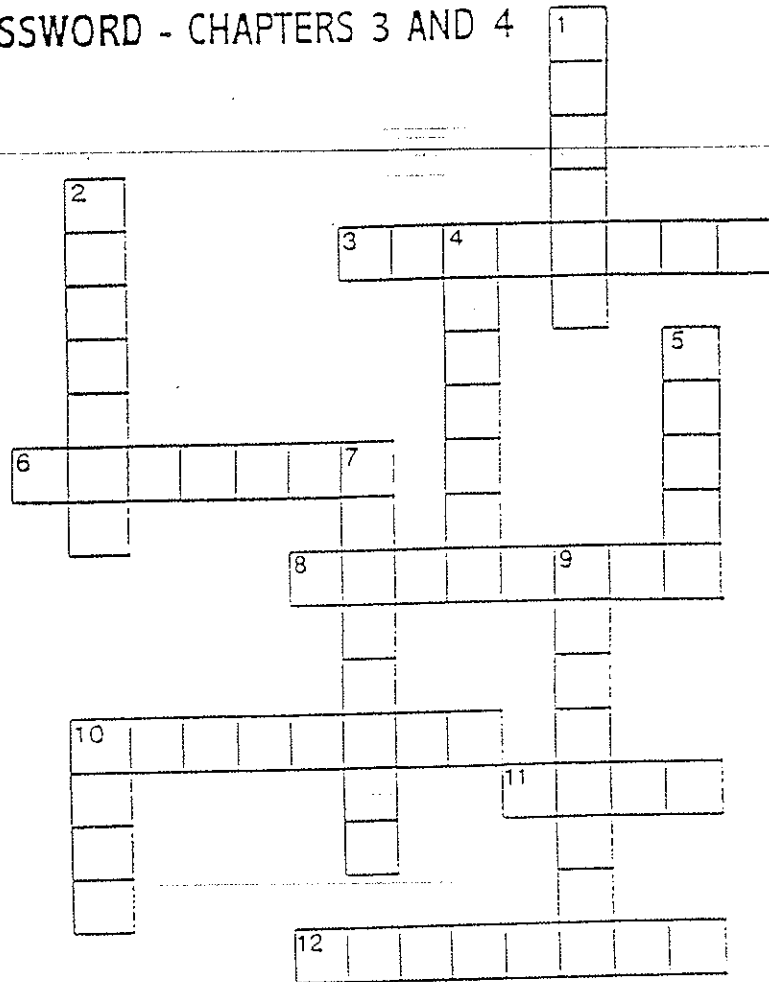
Procedure

1. Determine in advance a site where a variety of plants and organisms can be observed in association with a particular soil type. Record the characteristics of the soil in this community.
2. Describe the plants and animals that you observe in the soil community.
3. Collect equal proportions of top soil and sub soil (a total of a handful) and place them in a plastic bag for return to the classroom and further study.
4. Decide in what ways the lives of the plants and animals in this soil community are connected.
5. When your studies are complete, be sure to return the plants and animals that you examined.

Making Connections

- ✓ Which of the plants or animals are producers [green plants], first order consumers [plant eaters], second order consumers [carnivores], and decomposers?
- ✓ How might this soil community differ from another close by [e.g. meadow/forest]?

CROSSWORD - CHAPTERS 3 AND 4



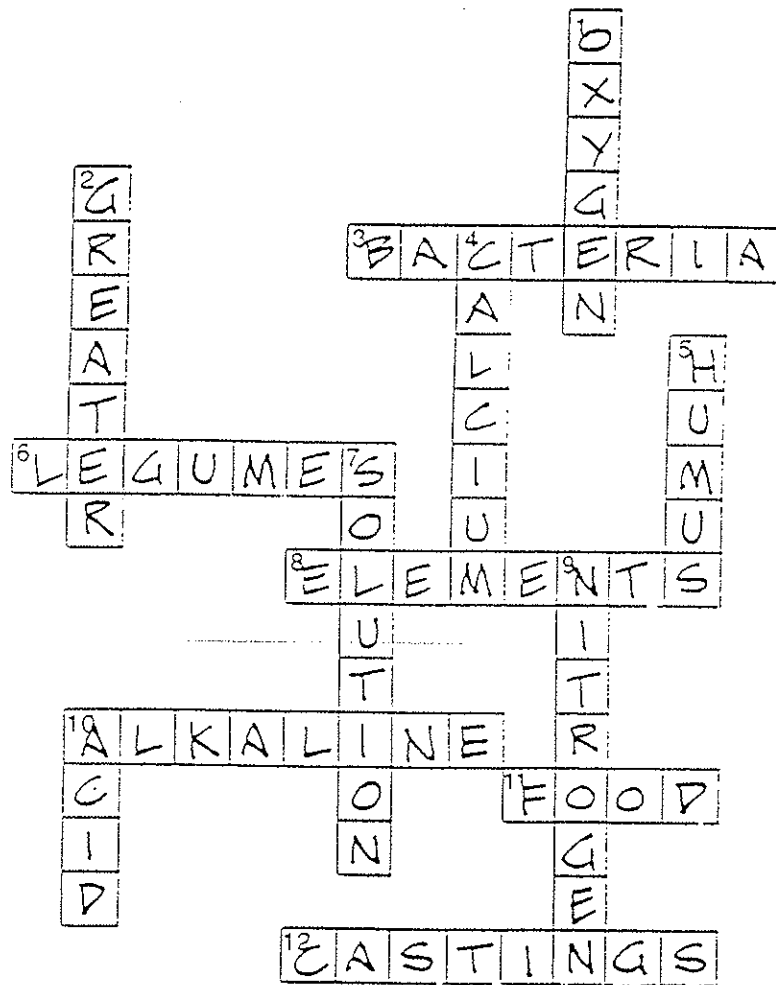
ACROSS

- 3 Legumes have _____ living in their root tissue.
- 6 Plants such as clover, alfalfa and peas are called _____.
- 8 Sixteen _____ are essential for plant growth.
- 10 There is low availability of micro-nutrients under _____ conditions.
- 11 Insects and worms use undecomposed plant tissue as _____.
- 12 Worms bring residue to the surface as _____.

DOWN

- 1 Higher plants obtain most of their carbon and _____ directly from the air.
- 2 The number of microorganisms in the soil is _____ than the number of macroorganisms.
- 4 When _____ is lacking, soils tend to be acid.
- 5 Soil microorganisms decompose plants and form _____.
- 7 Plants absorb nutrients largely from the soil _____.
- 9 _____ gives plants their dark green colour.
- 10 Soils are _____ when the pH is less than 7.0.

ANSWERS TO CROSSWORD - CHAPTERS 3 AND 4



CHAPTER 5:

SOIL MANAGEMENT

A major objective of soil management in Ontario is the control of soil degradation. Soil degradation is characterized by:

- a progressive loss of soil organic matter;
- soil structure deterioration and soil compaction;
- reduced available water retained in the soil; and
- topsoil erosion.

This has occurred as forage crops are no longer rotated with row crops (corn, etc.) because livestock has disappeared from an increasing number of farms. With continuing intensive tillage, soils become depleted in organic matter. This in turn leads to a deterioration in soil structure and reduced water infiltration. The poor soil structure and impeded water movement through the soil leads to increased surface runoff and erosion losses, especially on steep slopes. The lack of soil protection provided by hay or forage crops, and the removal of fence rows and woodlots, add further to wind and water erosion. [from Soil and Water Conservation and Development].

A good soil management program emphasizes the addition of organic matter, the maintenance of good soil structure, and the protection of the soil surface. These objectives can be achieved by proper cropping and tillage practices.

SOIL TILLAGE AND TILTH:

Soil tillage refers to the physical manipulation of soil to change its structure, incorporate residues and fertilizers, or control weed growth. It exerts a major influence on:

- water intake, storage, and evaporation from soil;
- on germination of seeds;
- root development; and
- water and nutrient extraction by plants.

Consequently, tillage is an important management factor for food and fibre production and control of sediment and nutrient losses from cropland.

Tillage benefits water intake and storage by establishing a macro- and micropore distribution which maximizes water movement through large pores and water retention by small pores. The larger pores formed with ideal aggregation not only allow rainfall to enter the soil, but permit drainage through the rooting zone to facilitate aeration through the drained pores. Tillage can also control capillary moisture loss from soil. Loosening surface soil can form a soil mulch which conserves moisture in the rooting zone by breaking the pore continuity required for capillary water movement.

Excess tillage can break down soil aggregates to primary particles, destroying the soil structure formed previously by good crop and residue management, contribute to compaction, accelerate erosion, and waste time and energy. In order to avoid the compaction of soils - which can restrict plant growth, water movement and soil aeration - it is recommended that plowing should be avoided on very wet soils in the fall, especially when they are dense and heavy.

With the increasing emphasis on conservation tillage, every effort is being made to encourage tillage programs which leave the soil surface roughened and with as much residue on it as is practical. This reduces soil erosion potential and promotes soil tilth.

Three precautions are made: avoid working soils

- 1) too soon [when wet];
- 2) too deep [into subsoil layer]; and
- 3) too much [to avoid breakdown of aggregates].

Also, plowing across the contour of the land is essential.

Soil tilth is frequently used to describe the suitability of a soil for the germination and growth of specific seeds.

A **fine tilth** is required for small seeds, whereas a coarser tilth is suitable for the larger seeds, such as beans and corn.

Tilth describes soil structure in terms of the size-distribution of the soil aggregates and their resistance to breakdown by tillage and rainfall. When soil is in good tilth, there is close contact between the seed and the aggregate, permitting moisture to move into the seed and start germination.

CROPPING PRACTICES:

Crop Cover

The type of crop grown and how it is managed will influence the productivity and erosion potential of the land. Continuous row crop production (e.g. corn, soybeans) has been increasing in Ontario due to economic incentives. The negative effects of concentrating only on these crops can be:

- a) a decline in organic matter - they have sparse rooting systems and their residue is more difficult to break down;
- b) a soil that is bare in winter; and
- c) increased compaction from the use of heavy machinery, especially on wet fields in fall.

Conversely, forage provides a good vegetative cover that will protect the soil from erosion and promote good soil structure. Vegetation acts as a physical protector, absorbing the energy of the raindrops before they reach the soil surface, and reducing the cutting action of whatever runoff may occur. The roots of plants exert an aggregating effect on soil particles as well as forming a physical binding in themselves. The roots also provide drainage channels, which allow water to infiltrate. Finally, plant residues can form small dams to slow down the runoff, which gives more time for water absorption by the soil.

Crop Rotation

The regular succession of different crops on a given area of land is often essential for maintaining soil structure and yields. Winter cereals and forage crops provide vegetative cover during winter and early spring runoff, thereby assisting in erosion control during this period of typically high runoff. In addition, a good crop rotation reduces the build up of insect and disease problems and a rotation including two to three years of grass-legume crop improves the structure, drainage and aeration of a clay soil.

Strip Cropping

Strip cropping is a method used to control erosion on long, smooth slopes. Fields are laid out in narrow strips across the incline, alternating the tilled crops such as corn with hay and grain.

Clover Plowdown

Clover is frequently seeded with a companion grain crop and then plowed down in fall after the main crop has been harvested. As it is a legume, it adds nitrogen as well as organic matter to the soil.

Finally, in discussing methods of erosion prevention, mention must be made of several engineering solutions to the problems of channel erosion. Some of the special control practices are:

- . land drainage
- . grassed waterways
- . gully control
- . diversion terraces, and
- . buffer strips.

Information on these techniques may be found in the literature and films that are under References at the back of this manual.

A COMPARISON OF SOILS

Purpose

To understand the effects that farming has upon the soil, and the role of forests in creating and improving soil.

Materials

- . soil probe or spade
- . tray or pail

Procedure

1. Find an area of cultivated farmland (not a pasture or meadow) near the woods.
2. Have the students take a sample of soil. Have them note whether the tool was easily inserted into the soil or not.
3. Collect the sample in the tray. Note the colour, texture and moisture content of the sample.
4. Carry the sample into the woods for comparison. Take a sample of forest soil from beside a rotting stump or log, and another sample from some distance away.

Making Connections

- ✓ Which soil is most compacted?
- ✓ Which soil has more humus or dead material? Why?
- ✓ Which soil has the most moisture. Why?
- ✓ Which soil would be best for the growth of plants?
- ✓ What role do woodlands play in conserving soil and water?

CROP COVER

Purpose

To observe how crop cover affects soil loss.

Materials

- . 2 small boxes approximately 40 cm long, 30 cm wide and 10 cm deep [these should be watertight - i.e., lined with plastic, tin, or tar];
- . 2 flower sprinklers 1L in size
- . 2 - 2L wide-mouthed jars
- . 2 sticks of wood approximately 2 cm thick
- . a piece of sod to fill one box
- . soil to fill the other box: two tin spouts.

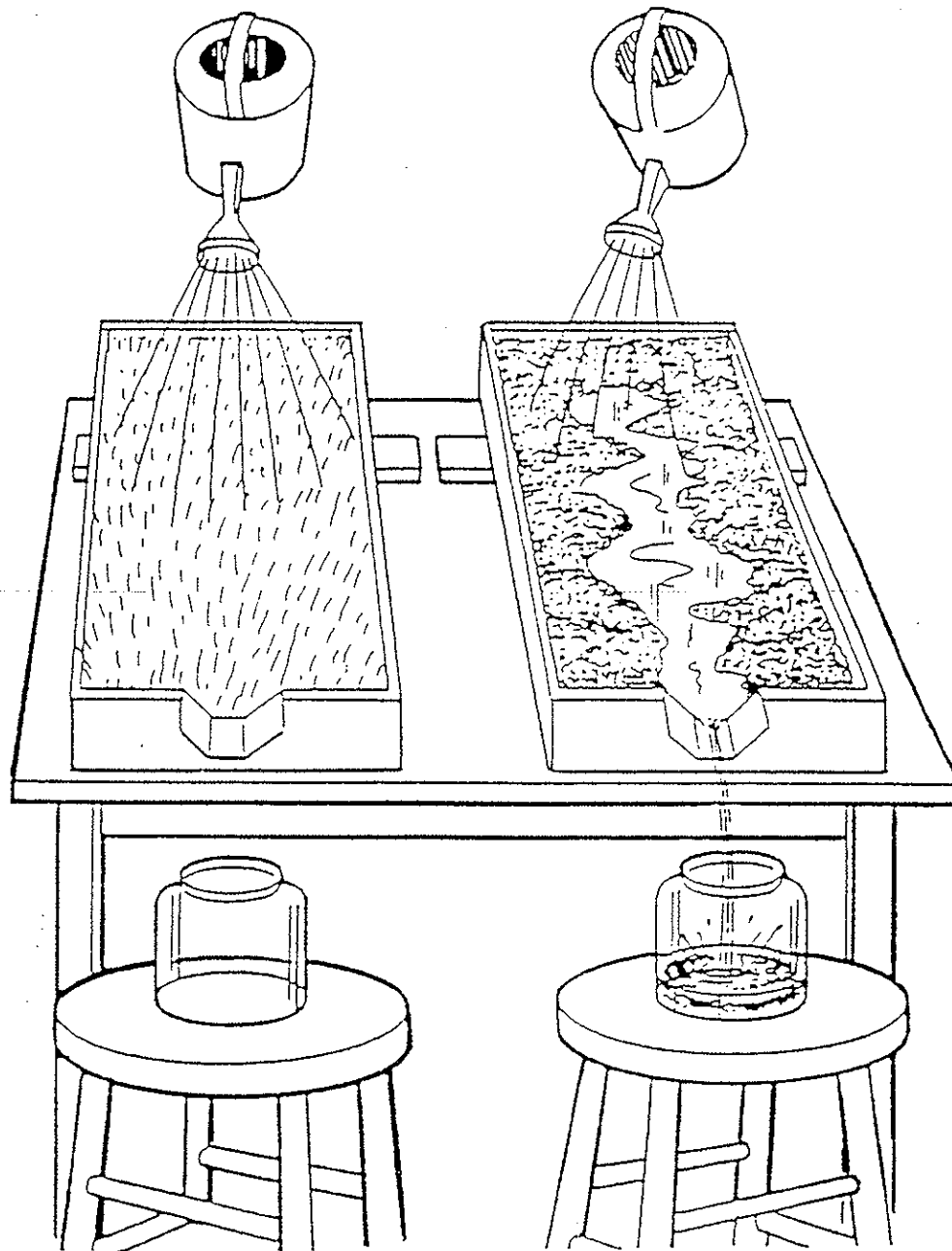
Procedure

1. At one end of each box cut a V-notch 3 cm deep and fit with a tin spout to allow water to drain into the jar.
2. Cut a piece of sod from a pasture or lawn to fit one of the boxes. Trim the grass with scissors so that it is not more than 3 cm high. [This makes it easier to handle].
3. Fill the other box with soil from the same place - i.e. don't try to pick a very poor soil.
4. Set the boxes on a table so that the spouts extend over the edge.
5. Place the sticks under the other end to give the boxes slope. Put the empty jars on stools placed beneath the spouts.
6. Fill the two sprinklers with water and pour the water steadily on both boxes at the same time and at the same rate. Hold the sprinklers the same height from the boxes.

Making Connections

- ✓ How quickly did the water enter each jar?
- ✓ What was the colour of the water entering each jar?
- ✓ How much water entered each jar?
- ✓ What conclusions can be drawn?

HOW DOES CROP COVER AFFECT SOIL LOSS?



SOIL MANAGEMENT

Purpose

To apply soil conservation techniques to a specific site.

Materials

A visit to a farm, a description of a farm [its soil types, its slope; crops grown, water bodies, etc.], or a visit to a site which has undergone construction.

Procedure

1. Have the students list the characteristics of the soil(s); the slope of the land; the degree of protection from wind; the current plant cover, and existing erosion problems.

Making Connections

- ✓ Describe the soil structure. What can be done to improve it? Is the farm (site) vulnerable to soil erosion? Why? **
- ✓ What can be done to ameliorate the existing erosion problems?
- ✓ What can be done to ensure protection from future problems?

** Soil erosion is affected by the following factors: rainfall, degree of slope, soil type [sands and loamy sands have the lowest potential for erosion; silt loams and silty clay loams the highest - generally], the amount of plant cover, and the way in which the land is managed.

APPENDICES

Appendix 1: How light affects plant growth.

The plant receives water and minerals from the soils which are carried into the veins of the leaves. Carbon dioxide is taken into the plant through the stomata, tiny openings on the underside of the leaf. Using the sun's energy and the chlorophyll in the leaf cells, the plant changes the carbon dioxide, minerals and water into sugar and oxygen, the sugar being food for plant growth. The process is called photosynthesis.

Appendix 2: Conservation Authorities

Conservation Authorities are organizations established by the Province of Ontario to manage watershed systems. They work under the auspices of the Ministry of Natural Resources. One of their mandates is to provide flood control, which they can do through ensuring that the lands in their area have good water holding capacity, and through dams and reservoirs. Fast-flowing flood waters can wash good topsoil away, as well as damage the existing ground covers.

Appendix 3: Pollution by Fertilizers

When excess fertilizers are applied on the land and poor erosion control is present, the fertilizers can move in run-off waters into streams and lakes. There the extra nutrients can cause excessive growth of plant material such as algae. When this material dies and decays, it robs the water of life-giving oxygen. This is called the process of eutrophication.

Appendix 4: Further Facts for Societal Implications Section

1. Approximately 60% of our best agricultural lands in Canada lie within 80 km of our major urban centres, and thus are threatened with changing use. For example, 2/3 of all urban growth in Canada from 1966-76 occurred on high capability agricultural lands.
2. Annual cropland soil erosion costs in Ontario are estimated at \$74 million.
3. Thirty-seven percent of Canada's Class 1 agricultural land is visible from the top of Toronto's CN Tower on a clear day.
4. Low prices offered to farmers for produce, together with increased production costs, have encouraged farming practices that reduce soil fertility.

Appendix 5: Soil Capability Classification

The Canada Land Inventory has used soil survey maps and reports to compile a soil capability classification for agriculture for Ontario. Seven land-use capability classes have been defined and were determined by the characteristics of the soil profile, slope, degree of erosion, stoniness, drainage and climate. Each land class is determined by the degree or intensity of these limitations to land use. Class 1 land has no significant limitations for a wide range of crops; the soils are deep, well-drained and occur on level or nearly level topography; there are no serious hazards to crop production and, under good management, they are often the most productive soils for many farm crops. At the other end of the scale, Class 7 lands are not considered suitable for agriculture, due to such factors as shallowness, steep slopes and/or short frost free periods. Almost one-half of the land area in Canada is totally unsuited for agricultural production; and a further 28% has low temperatures and is so rocky or dry that there is virtually no potential for agriculture.

REFERENCES

1. A Growing Concern: Soil Degradation in Canada. Science Council of Canada, 1986.
2. Best Management Practices - A First Look, Practical Solutions for Soil and Water Problems. Ontario Ministry of Agriculture, Food and Rural Affairs Factsheet. AGDEX 510.

2. Land: A Fragile Resource. Agriculture Canada, 1986. [Available from: Secretariat of the Canadian Agricultural Research Council, Research Branch, Agriculture Canada, Ottawa, Ontario K1A 0C5].
3. Ontario's Fertile Soil. Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). AGDEX 010, Order No. 92-031.
4. Ontario Soils. Physical, Chemical and Biological Properties and Soil Management Practices. Ministry of Agriculture, Food and Rural Affairs. Publication No. 492, AGDEX 500.
5. Soil Compaction. Ontario Ministry of Agriculture, Food and Rural Affairs. AGDEX 510, Order No. 88-082.
6. Soil Erosion: Its Agricultural and Environmental Implication for Southern Ontario. Available from: Secretary, Ontario Chapter SCSA, 740 York Mills Rd., Suite 506, Don Mills, Ontario M3B 1N7
7. Soil at Risk: Canada's Eroding Future. Available from: Clerk of the Committee, Standing Committee of Agriculture, Fisheries and Forestry, Committees and Private Legislation Branch, Senate of Canada, Ottawa, Ontario K1A 0A4.
8. Soil Science Simplified. Harpstead, M. I. and Hole, F. D. Iowa State University Press, 1980.
9. Soil and Water Conservation and Development: Ontario Documentation Soil and Water Management Branch, Ontario Ministry of Agriculture, Food and Rural Affairs, 1986.
10. Suitability of Conservation Tillage Systems to Ontario Soil Types. Ontario Ministry of Agriculture, Food and Rural Affairs. AGDEX 512, Order No. 90-198
11. The Nature and Properties of Soils. Buckman, H. O. and Brady, N. C. Macmillan Co., New York, 1984, 9th Edition. [A College Text].
12. Towards a Conservation Strategy - An Assessment of Conservation and Development in Ontario. Conservation Council of Ontario, 1986. Available from the CCO, Suite 202, 74 Victoria St., Toronto, Ontario M5C 2A5, Cost - \$10.00.
11. United States Department of Agriculture (USDA) Publications - Telephone (202) 447-5727
12. University of Guelph Publications

13. What Everyone Should Know About Soil. Ontario Ministry of Agriculture, Food, and Rural Affairs. Order No. 87-079, AGDEX 500/010.

AUDIO VISUAL MATERIAL

Materials available from:

A.V. Library
Ontario Ministry of Agriculture, Food and Rural Affairs
52 Royal Road
Guelph, Ontario N1H 1G3
Telephone: (519) 767-3622

NOTE: Postage is pre-paid both ways.

Earth, Wind and Water (10 min.) VIDEO (V5085) 1987
Discussion of conservation tillage, cropping system, and structural controls for erosion.

Land: Our Last Resource (20 min.) VIDEO (V5180) OR FILM (F5107) 1981
A look at the causes of soil erosion and methods of prevention. OMAFRA

Soil Today, Food Tomorrow (25 min.) VIDEO (V5289) OR FILM (F5181) 1984
Comprehensive look at methods of erosion control. OMAFRA

Microscopic Life in the Soil (14 min.) FILM (5119) 1968
Examines the form and functions of soil micro-organisms. Stanton Films

Land: The Threatened Resource (78 slides, audio cassettes, 15 min.) (S5081) 1976
Discusses the Canada Land Inventory, and urban encroachment on good farm land. Agriculture Institute of Canada

Worm Farming (9:12 min.) VIDEO (V5339) 1987
Shows how worms contribute to soil structure.

Youthful Outlook: Soil, The Vanishing Act (17 min.) VIDEO (V5378) 1991
The topic of soil erosion is tackled by a team of teenaged reporters in a news magazine style show targeted to grade 8 students. [Open caption available].

GLOSSARY

- Accelerated erosion- Soil erosion increased by human activity beyond the normal or geological rate.
- Acid - ~~A substance with hydrogen ions available for chemical activity.~~
- Acid soil - Soil with a pH value of less than 7.0, which is neutral.
- Aggregate - see Ped.
- A horizon - The natural surface layer of mineral soil.
- Alkaline soil - A soil with a pH value of more than 7.0, that is, basic.
- Atmosphere - The layer of gas surrounding the earth: nearly 80% nitrogen about 20% oxygen, and 0.03% carbon dioxide.
- Available plant nutrient - See Nutrient.
- Available soil water- See Soil moisture.
-
- Basic - Another word for alkaline, but often with emphasis on the presence of calcium and magnesium.
- Bedrock- The solid rock underlying unconsolidated surface materials.
- B horizon - Subsoil horizon lying below the A horizon.
- Biodegradable - Capable of being broken down into harmless products by living organisms.
-
- Capillary action- The action by which the surface of a liquid is elevated or depressed depending on the relative attraction of the molecules of the liquid for each other or a solid with which it is in contact.
- Capillary water - Water held in the finest pores in a soil.
- Cation exchange - The exchange between a cation in solution with one on the surface of a soil particle.
- C horizon - Less developed soil lying below the A and/or B horizon(s).
- Coarse earth - The part of mineral soil that is too coarse to pass through a 2 mm sieve. Coarse earth consists of gravel, cobbles, and stones.
- Colloidal particles - Clay and organic particles that are so small they tend to remain suspended in standing water.
- Compost - A combination of organic matter, soil, nutrients, moisture, and lime, which when allowed to rot can be returned to the soil as a fertilizer and conditioner.
- Crust of soil - A somewhat dense, hard or brittle soil layer at the land surface.
- Cycle - A repetitive natural sequence of changes in a substance. Examples are the water and nitrogen cycles.
-
- Drainage - Removal of water from a soil. Can be natural, that is, well or poorly drained, or artificial by use of tiles.

Erosion -	The process by which soil is washed, blown, or otherwise moved by natural agents from one place on the landscape to another.
Evaporation -	The change of the state of water from a liquid to a gas, as happens at the surface of bare soil.
Evapotranspiration -	The transfer of water vapour to the air by a combination of evaporation and transpiration.
Fauna -	The animals present at a site or in a region.
Fertilizer -	Any material that is added to soil by people to supply plants with more nutrients.
Field capacity -	The water content of a soil two or three days after having been wetted and after free drainage has reached the point of being negligible [obsolete in technical work].
Flora -	The plants present at a site or in a region.
Friable -	Soil material is easily crushed under gentle pressure.
Glacier -	A large body of slowly moving ice.
Glacial drift -	Deposits made by glaciers and their meltwaters, including till and outwash.
Glacial till -	Unsorted debris left by a glacier.
Green manure -	A growing crop that is plowed under and mixed with the soil to enrich it with organic matter.
Groundwater -	The water in fully saturated pores in underground rock formations.
Hardpan -	A soil layer that acts as a barrier to movement of water and extension of plant roots.
Horizon -	A natural soil layer, either surface soil or subsoil, that formed parallel to the land surface during the natural development of the soil body.
Humus -	The dark, rather stable part of soil organic matter that remains after the major portion of animal and plant residues have decomposed and disappeared in the form of water and gases such as carbon dioxide.
Infiltration -	The downward entry of water into soil.
Ion -	An electrically charged atom, with a surplus or deficiency of electrons.
LFH Horizon -	A thin surficial organic layer on soil, such as leaf litter.
Landform -	A natural feature of the earth's surface such as a hill or a plain.
Landscape -	All the features of the surface of the land that together distinguish one region from another, including soil
Leaching -	The removal of materials in solution by downward movement of water through the soil.
Lime -	Ground limestone or dolomite.
Limestone -	A rock rich in calcium carbonate consisting chiefly of organic remains.

Manure -	Excreta of animals, with or without bedding litter, added to soil to improve it with respect to crop production. See also Green manure.
Matric force -	The force of attraction between water and soil particles that holds capillary water in the soil.
Mineral -	A particular kind of natural crystalline substance such as quartz.
Mites -	Arthropods that are abundant in soil.
Moraine -	A blanket or ridge of unsorted debris left by a glacier.
Mottles -	Spotted areas of colour in a soil, usually associated with periodic wet conditions.
Muck soil -	An organic soil that is more than half decomposed in the sense that visible organic fibers constitute a minor portion of the mass.
Mulch -	A layer of material spread over the soil surface to protect it and plant roots from erosion, crusting, freezing, and drying.
Nitrogen cycle -	The biochemical changes that take place in repetitive sequence as organisms take up and release nitrogen.
Nutrients -	Substances essential to the growth of plants, such as nitrogen, phosphorus, and potassium. An available nutrient is one that can be readily taken in by the soil.
Organic gardening -	Gardening without the use of commercial fertilizers. Emphasis is on the use of composted materials, green manures, and judicious arrangement of plants and associated beneficial organisms.
Osmosis -	The diffusion of water through a differentially permeable membrane, such as a root hair, from an area of high water concentration to an area of lower water concentration if pressure and temperature are equal on each side of the membrane.
Outwash -	Deposit made by flowing meltwaters from glaciers.
Parent material -	Rock material from which a soil forms.
Particle size distribution -	Proportion of clay, silt and sand particles in the fine earth of a soil.
Peat -	Relatively undecomposed fibrous organic soil.
Ped -	A unit of soil structure in a soil horizon, may be blocky, platy, or granular. A soil aggregate is the same as a soil ped.
Percolation -	The downward movement of water in soil.
pH -	The degree of acidity of alkalinity. The hydrogen potential expressed by a set of negative logarithmic values such that low numbers such as 3 and 4 signify great acidity and high numbers such as 8 and 9 signify low acidity [that is, high alkalinity]; pH 7.0 is neutral, that is, neither acid nor alkaline.
Precipitation -	Rainfall and snowfall plus minor amounts of dewfall and fog drip.
Productivity -	The capacity of a soil to produce plant material. This is expressed in yields per unit per unit time.
Regolith -	Loose earth materials above solid bedrock.
Relief -	The range between highest and lowest elevations in a region.
Runoff -	That part of the precipitation that eventually flows into streams either by direct surface flow or delayed subsurface flow.

Sandstone -	A sedimentary rock usually of quartz, bound together by cement such as silica or calcium carbonate.
Saturation -	The condition of a soil when all pores are filled with water. Base saturation percentage refers to the proportion of bases in cation exchange material.
Shale -	A sedimentary rock made of clay, silt, and very fine sand.
Soil -	A naturally occurring body of mineral and organic materials with form, arrangement, and composition developed at the surface of the lithosphere on land.
Soil classification -	A shorthand system to provide detailed soil description.
Soil formation- [genesis]	The processes by which parent material is transformed into a body of soil.
Soil moisture -	Water contained in soil. Available soil water is that which can be readily taken up by the plant.
Soil reaction -	Degree of acidity or alkalinity (pH).
Soil structure -	The clustering of soil particles into units called peds or aggregates.
Soil survey -	The identification, classification, mapping, scientific and practical explanation, evaluation, and interpretation of the soil cover of a terrain.
Soil texture -	The relative proportions in a soil sample of the three soil separates: sand, silt, and clay.
Solum -	The A and B horizons together or the single one of these that overlies the C horizon at a site.
Stomata -	Minute openings in a leaf that permit gaseous interchange.
Substratum -	A layer beneath the surface soil.
Tilth -	The physical condition of soil as related to its ease of tillage and fitness as a seedbed.
Topography -	The lay of the land, that is, levelness or hilliness.
Transpiration -	The transfer of water to the atmosphere through the stomata of plant leaves.
Unsaturation -	The state of a soil in which not all pores are filled with water. Usually the largest pores are air filled and the smaller pores are water filled.
Watershed -	An area draining ultimately to a particular body of water.
Water table -	The surface of the groundwater.
Weathering -	The disintegration and decomposition of minerals and rock.
Wilting point -	The condition of a soil when its water content is so low that plant roots can no longer obtain adequate water to sustain life.
Windbreak -	A planting of vegetation to protect downwind crops from desiccation and breakage and to protect soil from wind erosion.

[Condensed from Soil Science Simplified]