

SOIL MANAGEMENT INSTRUCTION IN AGRICULTURE CLASSES

Organized Subject Matter on Units in Soil  
Management for Use of Teachers and Students  
of Vocational Agriculture in Virginia

BY

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1.

PART I

PROBLEM

What should be the content of a course in Soil Management in Vocational Agriculture in the high schools of Virginia?

The proposed problem is to make a study of the present practices and the organization of the content of teaching units in Soil Management on the secondary school level.

## OBJECTIVES

Teachers of Vocational Agriculture realize that there is a great need for practical teaching units on Soil Management on the secondary school level. While there is an abundance of materials on this subject, most teachers and supervisors will agree that it is too technical and not in suitable form for use in high school. The following objectives have been set up with a view to meeting this situation:

1. To determine the nature and content of Soil Management jobs or units now being taught by teachers of agriculture in the high schools.
2. To set up a proposed course outlined in Soil Management for use by teachers in the high school.
3. To organize the desirable content of Soil Management units to be taught by Vocational Agriculture teachers.

## PROCEDURE

In securing and organizing the data of this study the following procedure was used:

1. Secured by questionnaire from teachers of agriculture in Virginia the following information:
  - a. The number of soil management units now being taught and the time devoted to such instruction.
  - b. The number of soil management units that the teachers think should be taught and the time that should be devoted to such instruction, provided suitable units are made available.
  - c. Suggested lists of needed units.
  - d. Schedules for teaching such units.
2. Prepared a list of units for soil management instruction in Virginia.
3. Secured and organized as reference material for student use the material for the selected units.
4. Prepared a complete set of lesson plans designed to aid teachers of agriculture in the teaching of the soil management units.
5. Had five experienced agricultural teachers read and criticize each unit and made such revisions as seemed advisable.

## SUMMARY OF QUESTIONNAIRE

The following soil management units were designated as being desirable to teach. The selection of these units was based partially on the replies of 71 white teachers of Virginia. There was some variation in the choice of units that should be taught. The lowest number of teachers choosing any one unit was 30 and the highest was 53.

NAME	FREQUENCY	RANK
The origin of soils	45	4
Physical properties of soils	47	3
Soil organisms	53	1
Organic matter in soils	52	2
Soil water	36	10
Soil tillage	30	12
Crop rotation	40	6
The plant food elements	38	8
Soil acidity and its control by liming	37	9
Green manures	31	11
Farm manures	39	7
Special soil erosion control practices	44	5

The number of complete written lesson plans the teachers have available on soil management are indicated below:

Average for 71 white teachers of Virginia	4
Number indicating a desire for prepared plans	68

5.

Teachers were asked to indicate their one greatest need in teaching soil management. The following results were obtained from those teachers replying to this question:

Needs of agricultural teachers in soil management instruction

NEED	NUMBER OF TEACHERS
Providing suitable references	23
Finding sufficient time in the teaching calendar	14
Providing suitable lesson plans	27
Organized technical information on unit basis	37
Securing pupil interest	4

General information computed from information submitted by 71 teachers

Average length of class period	60 minutes
Average years of teaching experience	10. 1

The situation in Virginia with respect to the number of soil management units being taught and the number the teachers think should be taught is shown in the table below. In each year, it seems, teachers would like to increase the number of units they are now teaching.

Soil management units taught in Virginia

71 white teachers

	Freshmen	Sophomores	Juniors	Seniors
Total units taught	288	307	373	342
Should be taught	332	337	415	407
Amount of increase	44	30	42	65

Teachers were asked to list reference material that they are now using. Sixty different references were listed as being used for teaching soil management. Listed below are the references arranged in order of frequency. The list includes all the titles that were selected by five or more agricultural teachers.

Number of teachers	Title
22	NATURE AND PROPERTIES OF SOILS, T. Lyttleton Lyon and Harry O. Buckman
20	SOILS AND MAN, Yearbook of Agriculture 1938
14	PRODUCTIVE SOILS, Wilbert Walter Weir
8	PRODUCTION OF FIELD CROPS, Hutcheson, Wolfe, Kipps
5	SOIL CONSERVATION, Hugh Hammond Bennett
5	FARM SOILS, Edmund Louis Worthen

PART II

UNIT I

THE ORIGIN OF SOILS

I. Factors of soil formation

A. Formation of parent material

1. Three kinds of rocks forming soil material

- a. Igneous
- b. Sedimentary
- c. Metamorphic

2. Physical agencies of weathering

- a. Heat and cold
- b. Freezing
- c. Glaciers
- d. Erosion of streams
- e. Waves
- f. Wind
- g. Plants

3. Chemical agencies of weathering

- a. Hydrolysis
- b. Carbonation
- c. Hydration
- d. Oxidation
- e. Solution

B. Climate

C. Texture of the rock

D. Organic matter

E. Microorganisms

F. Topography

G. Time

II. Topsoil and subsoil

## THE ORIGIN OF SOIL

What is soil? Soil is a mixture of disintegrated and decomposed rocks and minerals, organic matter, water and air, in greatly varying proportions. It has more or less distinct layers or horizons developed under the influence of climate and living organisms.

### Factors of Soil Formation

#### Formation of Parent Material

Soil development begins with the formation of parent material, accumulated through physical and chemical weathering of rock. Climatic and biological actions produce most of the identifying characteristics of the soils of the great soil groups, however, many of their subdivisions owe their distinctive characteristics to parent material.

The term rock weathering means the breaking down and decomposing of fresh rock into fragments and mineral particles into the layers of material or mantle that covers the bed rock. These layers consist mostly of small particles which have been changed by wind, rain, heat, and cold, for hundreds of years. The mineral rocks furnish a very large proportion of the material for most soils.

#### Three Kinds of Rocks Forming Soil Material

Rocks include both consolidated (hard), and unconsolidated (soft) minerals, and organic deposits of the earth. Rocks of the earth are divided into three classes: 1-Igneous; 2-Sedimentary, eolian, and glacial; and 3-Metamorphic.

Igneous rocks are formed by the hardening of molten minerals within the earth, such as, lava rocks formed through volcanic action. Coarse crystalline texture is produced when the lavas cool slowly, while fine crystalline and glassy texture results when lavas are cooled quickly.

Rocks are named chiefly in accordance with the kinds of minerals making up their mass, the proportion of the different minerals may vary considerably. Some of the rocks are acidic in character, being made up almost entirely of quartz while others are basic containing a high portion of iron, calcium, magnesium, and other basic elements. Granite may consist mainly of a mixture of potash, feldspar, and quartz, in others, mainly of quartz, hornblends, with little feldspar. Soils from granite and crystalline rocks containing potash-feldspar with phosphoric acid and a good supply of potash, however they are deficient in lime.

Sedimentary rocks are either consolidated or unconsolidated rock material formed from gravels, coarse sand, shell, deposited by water. Some of the sedimentary soils have been laid down in lakes and swamps. However, most sedimentary rocks have been deposited in the ocean, and are known as marine soils. The coarser material such as sand and gravel are deposited near the shore. The fine sand, silt and clay, are deposited to greater depth and in quieter water.

One form of sedimentary rocks is conglomerate, composed of gravels and coarse sands; sandstone, composed of sands of varying size and proportions that may be easily crumbled with the fingers; or it

may be extremely hard rock. Clay and shales are often called "mud stones". They are deposited in quiet water. Some of the clays and shales contain a high percentage of lime, others have none, while some have a quantity of mica. Still others have a high percentage of silica. Productive soils are more likely to develop from highly calcareous clays than from those containing no lime.

Limestone soils may be developed from very hard stone composed almost entirely of calcium carbonate or of a mixture of calcium carbonate and magnesium carbonate (dolomitic limestone). Others are soft and chalky and contain a high per cent of clay and sand.

Sedimentary rock often occur in alternate beds or strata. Flint and chert are often deposited within the limestone. They are very hard and resistant to weathering, therefore, slow in forming soil.

<sup>2</sup> Eolian (wind) deposits are unconsolidated rock that are important soil materials. These deposits are composed of loess (accumulations of dust) and sand, and are present near the edge of deserts. Usually loess deposits contain a plentiful supply of plant nutrients, including more or less free carbonate of lime. Sand dunes appear near the margin of deserts and are usually composed mostly of quartz. They are unimportant sources of material for soil formation. They may be a source of destruction migrating over the land destroying crops and forests. Glacial deposits resemble unconsolidated conglomerates and are composed of fragments of many kinds of different rocks. For this reason they usually contain a fair to plentiful supply of mineral plant

nutrients. Soils developed from these deposits comprise the most important types in the northern part of the United States.

When igneous and sedimentary rocks have been greatly changed from their original condition by intense heat or very high pressure, their structure and mineral content are considerably changed. The products are called metamorphic rocks. The resulting changes may be mainly physical, as when a pure limestone is changed to a marble of practically the same composition. Often there are chemical changes. Metamorphism is caused by the following agents: heat and pressure, hot water, and gases.

There are two kinds of metamorphic rocks, the foliated (banded) and the non-foliated. Among the foliated rocks are included gneiss, schist, and possibly slates. The gneiss rocks are coarsely banded with the bands commonly of different minerals; very often the light colored bands contain quartz and feldspar and the dark colored bands, iron and magnesium minerals. The gneiss break down rather easily into soil material and are important soil formers in the Piedmont plateau of Virginia.

Schists are the metamorphic product of several kinds of rocks, and vary greatly in composition. Mica is a very common mineral in schist. Schists are usually soft and crumbly and are not suitable for structural purposes. Soils developed from schists are usually poor in lime and potash. Slates have a high degree of cleavage and have well known quality of splitting easily. Slate and shale closely resemble each other. Slates range in color from blues, reds, brown, purple, black to

gray. The slate belt in Virginia lies in the folded rocks of the Appalachians. Although slate breaks easily into sheets under weathering, further change is slow and soils formed from it usually contain fragments of slate.

The non-foliated rocks include marble and quartzite. Quartzite is the result of metamorphism of quartz sandstone or conglomerate and is composed mostly of quartz. Soil forms very slowly from this rock, and usually soils developed from it are unproductive regardless of climatic conditions.

#### Physical Agencies

The physical agencies of weathering are responsible for the disintegration of rock, by mechanical forces reducing rock to size particles that make up soil material without affecting it chemically. Physical forces predominate in cool climates. With physical forces the soil is made into granular form or sand particles.

Rocks are poor conductors of heat and the high temperature of rocks extends only a slight depth. More expansion takes place on the surface producing a strain that often causes a layer to break off. Also different minerals within the rock expand and contract at different rates due to temperature changes of day and night causing cracking, splitting, and crumbling of the rock.

Water enters the coarse grained surface and crevices of rocks, and as water increases its volume about nine per cent on becoming ice and exerts a force of one hundred fifty tons per square foot, it produces a tremendous disintegrating force in reducing rock to soil material.

During the glacial period all of the northern part of the United States was covered with a great ice sheet. Often the ice sheets were several thousand feet thick, over-riding hills and mountains. Masses of rocks were picked up and embedded in the ice increasing its cutting power. The tremendous weight made the grinding and scouring break down even the hardest of rock as it traveled at a rate of a few feet to one hundred feet per day. When the glaciers melted they unloaded pulverized, well mixed, material as soil material.

Streams and rivers collect rock fragments, sand, and gravel, and roll them along their beds, grinding them into finer particles. Clear water cuts rather slowly, but when it is charged with sediment the abrasive power is increased greatly. The grinding power of water depends on two things: the amount of substance suspended in the water and the speed of the stream. The weight of individual particles carried in suspension by a current varies as the sixth power of its velocity. Doubling the speed of a current enables it to carry particles sixty-four times as heavy as before. The fine particles intermixed with material from different sources are carried by the stream and deposited on flood plains and deltas.

The waves along the shores of lakes and seas are responsible, in many cases, for breaking down great masses of rock cliffs into rock fragments, pebbles, and fine material, and carrying them away to be deposited in deep water and sheltered bays to form bars.

The wind as a soil forming agent wears down solid rocks and coarse material into dust. The wind in the desert, and semiarid regions where vegetation is scarce, is likely to be of high velocity, and the impact of sand particles against rocks and each other scours them down into fine particles. In arid regions the effects of winds carrying dust and sand is very serious. It may sweep away everything except the bed rock, transporting the soil and building up soil in distant plains.

Mosses and lichens will develop on rock ledges sending their roots into the crevices and fissures, where they exert a prying and loosening effect. These simple plants catch dust and humus; finally enough material has collected to support higher plants. The higher plants exert still greater pressure in prying the rock apart.

#### Chemical Agencies of Weathering

The changes brought about by chemical agencies change the composition of rocks and the effects are called decomposition. Chemical forces predominate in the warm or hot climate.

Hydrolysis is the main process by which the chemical weathering of rocks takes place. Hydrolysis is the process by which water reacts with the minerals, breaking up large masses of rocks into finer material, to form secondary products. It is the exchange of component parts between the mineral and water. The change may be illustrated as follows: When water comes in contact with a simple mineral such as calcium silicate, some of the mineral dissolves, and the water reacts

with the silicate to produce some calcium hydroxide and silicic acid.

Carbon dioxide, which is part of the air and is a product of the decaying vegetable matter present in most soils, combines with the water circulating among the rocks. Carbonation is the union of carbon dioxide with a base. For example, the calcium hydroxide, which may be formed by hydrolysis, unites with carbon dioxide to form calcium carbonate.

Hydration is the process by which water combines with various compounds to make hydrated minerals. The minerals found in rocks unite with water, become soft, lose their luster and elasticity, and increase their bulk, which tends to rupture the rock causing it to crumble. As a result other agencies may continue the weathering process more easily.

Oxidation is usually the first chemical force to be noticed in the rocks since it takes place near the surface. The oxygen of the air acts upon iron to form iron oxide and sulfuric acid discoloration is shown on the rock. The iron oxide in the form of scum resembling iron being soluble, is washed out and the rock is crowded and crumbled.

Water is a universal solvent, that is, most soil material, to some extent, is soluble in water, and as water circulates through rocks and soil material its efficiency as a solvent is greatly increased by the carbon dioxide it absorbs from the atmosphere and soil air. Thus the solution is largely a process of carbonation.

Solution is very important on the more soluble rocks such as gypsum or limestone. Hydrolysis, oxidation, carbonation, hydration, and solution act in unison to bring about the chemical decomposition.

#### Climate

Climate which includes the temperature and rainfall, is responsible for the major soil differences. Climate influences soils both directly and indirectly. Under dry conditions the physical forces will dominate and the soil formed will be coarse. Freezing, thawing, heat and cold, wind and the effect of animals, will be the principal agents. Desert soils are leached very little and usually contain more or less lime and other soluble salts.

In humid climates, the physical weathering which disintegrates, and the chemical forces which decompose some of the essential elements, are both at work and the soil material formed will be finer in structure. The soil in the humid section will usually be acid in reaction due to the leaching of calcium.

Climate and native vegetation work together as important soil forming forces. In cool climates soils accumulate more organic matter, which accounts for the darker upland soils of cool humid regions. The well drained upland soils of the warm regions of the South are red and yellow, and are not rich in organic matter, because of the very rapid chemical weathering. They have red subsoils and are usually acid. Most weathering takes place at the surface and the exposure of the rock will determine the kind and rate of decay.

### Texture of the Rock

Texture of the rock is a factor influencing the soil formation. Usually a coarse crystalline rock will disintegrate and decompose more rapidly than one of finer grain. Mineral composition of the rocks definitely influences the soil material formation. Rocks composed of minerals that are readily soluble and offer little resistance to decay are very slow to form soils. Freezing prevents the percolation of water through the soil and slows down the soil forming process. Dark colored rock, because of greater absorption of heat, are subject to greater differences in temperatures than light colored ones, resulting in more rapid disintegration.

### Organic Matter

Organic matter is a factor in the formation of soil. Plants and animals furnish organic matter. Soil material is the disintegrated, decomposed mineral rocks. After some organic matter has accumulated in the soil material, it has developed into a soil. It may be said there is no soil without organic matter, although the content in the soil varies widely. The primary source of organic matter is vegetation that develops on it and accounts for the change in color of practically all soils.

### Microorganisms

Microorganisms serve an exceedingly important function in the development of soils and their preparation for the growth of higher plants; their most important function being that of changing raw

plant and animal waste into soil organic matter. (See unit on Soil Organisms for further discussion.)

### Topography

Topography is a factor in soil formation. Topography influences soil formation through its effect upon drainage, run-off, the amount of water circulating in the soil, and the degree of erosion. Soil profiles on steep slopes are usually not strongly developed, except where there is heavy rainfall, warm climate, and dense vegetation. This slow development is due to rapid erosion, the reduced percolation of water through the soil, and lack of water in the soil for thrifty growth of plants responsible for soil formation.

The amount of water passing through the soil determines to a large measure the degree of profile development. Soils are darker on northerly slopes than on southerly slopes and soil moisture is higher due to less evaporation of moisture by the sun and the greater density of vegetation.

### Time

Time is a factor in soil formation. It requires time for the development of soils from parent material. The length of time required for the formation of a given type of soil depends on the other factors involved. Perhaps 100 to 200 years may be sufficient to develop a soil on acid materials containing an abundance of quartz sand and a covering of dense forest growth, under a cool and very humid climate. The time

required for the development of a normal soil is usually much longer in dry regions than in humid ones.

Soils may be formed quickly on flood plains because of the continuous accumulation of materials. These soils are usually fertile depending on the parent material and degree of development before being transported.

#### Topsoil and Subsoil

The term topsoil or surface refers to the furrow slice about seven inches in thickness, usually a more loamy and darker-colored layer than the lower layer. Organic matter and fertilizers are incorporated in this stratum and the roots of most of the common crops are confined here. The darker color produced by the larger content of organic matter distinguishes this layer from the other layers. The texture of the surface soil is usually a little coarser since the finer particles have either percolated down or have been removed by surface water.

The subsoil extends to an indefinite depth but is sampled to 40 inches in humid climates. This layer usually contains but little organic matter and the preparation of organic matter is not carried on very actively in this layer. This stratum is important because, capillary movement, root penetration, and resistance to drought depend largely upon its character.

UNIT II

PHYSICAL PROPERTIES OF SOILS

I. Color

A. Factors influencing soil color

1. Mineral material
2. Organic matter
3. Iron compounds

II. Soil texture

A. Size of soil particles

B. Factors influencing soil texture

1. Sand
2. Silt
3. Clay
4. Loams

III. Soil structure

IV. Temperature

- A. Compaction
- B. Moisture
- C. Slope
- D. Color of soil

V. Means of developing and maintaining favorable soil structure

- A. Grasses and legumes in rotation
- B. Organic matter
- C. Tillage operations
- D. Drainage

## PHYSICAL PROPERTIES OF SOILS

Soils differ widely--some are light or sandy, some are heavy or clayey, some are loamy, some are red or black, and some are described by other characteristics. An understanding of the facts that account for these differences may be a valuable help in deciding which land is likely to be the most productive, and most profitable for a farmer to buy. The properties of certain soils determine the practices that must be followed in order for crops to be grown profitably.

## Color

The color is probably the first property of the soil noted as one observes it. The color always appeals to practical farmers as one of the best means for indicating soil differences. Three factors are mainly responsible for the color in soils: the mineral materials themselves, organic matter, and iron compounds.

In some cases the mineral materials themselves give color to the soils. Sometimes in the Piedmont Plateau when rocks containing mica are decomposed, the mica remains in large flakes, giving the soil a glittering appearance. Where an abundance of quartz sand is found, the soil will have a grayish or whitish cast.

Usually, the dark brown or black colored soils are regarded as being the most productive. The dark brown or black color is usually due to the high content of organic matter, and is thus associated with favorable structure and good supplies of nutrients such as calcium and nitrogen. The presence of limestone imparts a darker color to organic matter and

hence to the soil. Limestone further aids by preventing the leaching out of black humus from the soil.

The color in itself cannot be taken as a final measure of the productivity of the soil. Sometimes dark colors may be due to improper drainage or swamp conditions or due to the high content of some mineral such as graphite. Usually, black or dark brown soils are the most productive, the red or reddish-brown ranking next in productivity and the yellow, gray or white soils being the least fertile.

Red soils owe their color largely to compounds of iron, known as ferric oxide. This form of iron does not exist in poorly drained soils, therefore, red color usually implies good drainage and good aeration. Due to the presence of this oxide, many of the subsoils of the Piedmont Plateau are red in color.

Yellow colors in soils are thought to be due to hydrated iron oxides. Yellow soils have low inherent productiveness and often have improper drainage.

Gray or bluish gray subsoils are characteristic of slow or poorly drained subsoils. The gray is often mixed with yellowish or rust brown blotches of soft concretions of iron compounds. The normally well drained soil in this section of the United States has a yellow or yellowish colored lower subsoil.

#### Soil Texture

Texture is a term used to express the size of the mineral particles in the soil. The texture of a particular soil may be coarse, medium or

fine depending on the group of particles that predominate. Soil particles are classed accordingly into three principal groups called sand, silt, and clay. The particle size of each range between certain limits:

Sands	2 to 0.05 mm.
Silt	0.05 to 0.002 mm.
Clay	less than 0.002 mm.

Sand particles and fine gravel are the coarsest and heaviest soil grains and can be readily seen by the unaided eye. They do not cohere when wet, and they feel rough and gritty to the fingers. Sandy soils have large pores and drain so feely as to be distinctively droughty. Aeration takes place so freely that organic matter in them "burns out" readily. However, sands being loose and incoherent are easily tilled. Sands include all soils of which the silt and clay make up less than 20 per cent of the material by weight.

Silt has the appearance and feel of flour when dry and is less sticky than clay when wet. Soils that contain some clay, much silt and considerable very fine sand are called medium textured soils, while soils which have a large proportion of finer silt and clay are called fine textured soils. Soils composed largely of silt particles usually have satisfactory drainage and aeration. Silt generally has a mixture of finer particles that make it almost ideal from the physical standpoint for the production of many crops.

Clay particles are the finest of individual soil particles and can only be distinguished with the aid of a microscope. Clay soils

are very plastic when wet and hard and cloddy when dry. Clay soils are very tenacious, that is, they are very resistant to rupture or separation of particles; therefore, more power is required to pull plows and other tillage implements through such soils in contrast to the easily tilled sandy soils. Due to the heavy draft of tillage implements through clay soils, they are known as heavy soils.

Loams consist of nearly equal proportions of light and heavy properties, the sand furnishing approximately half of the coarse properties and the silt and clay together furnishing the fine material. Loams are highly desirable for crop soils for they are more favorable for crop production than any other class group.

#### Soil Structure

Structure refers to the arrangement of soil grains within the soil mass. Structure affects such soil conditions as aeration, water, movements, and heat transfer. The important physical changes made by the farmer in making his soil better suited as a foot hold for plants are structural rather than textural. It is just as important to the farmer to maintain a favorable structure in cultivated soils as it is to maintain soil fertility. Plowing heavy soils when they are wet forms clods, which may interfere with tillage and crop production for many years.

The structure of soils mainly determines the ease with which roots can penetrate, the rates of absorption, and movement of water, the tilth and mellowness at any given time, and the resistance of the soil to erosion. The crumb and granular structures are the most favorable for the growth of crop plants.

### Temperature of the Soil

The temperature of the soil is very important for favorable chemical and biological activities within the soil. Seed germination and plant growth depend upon favorable temperatures although it may vary widely, being low for such crops as blue grass and high for corn and watermelons. A cold soil is not conducive to the rapid growth of most agricultural plants. The energy by which the soil maintains its normal activities comes directly or indirectly from the sun and the temperature of any particular locality depends primarily upon the climate.

A number of conditions determine the temperature of soils, some of which may be controlled by the farmer. The farmer may overcome some of the uncontrollable factors by adapting the crop best suited to the climate.

The temperature of the soil is determined to a considerable extent by its own properties. The two most important of these are soil compaction and soil moisture. A soil with a large amount of air space is a warmer soil than a soil with less air space. Compact soils have a high heat conductivity and are thus colder than loose soils.

The degree of slope and direction of the slope influence the temperature. Southern exposures are always several degrees warmer than northern exposures. Temperature differences between exposures increase with increased slope due to the angle of the sun's ray. The significance of exposure is often very noticeable in the type of vegetation on the north and south exposure. Peaches grown on southern

slopes often blossom out so early under the influence of the midday sun as to be injured later by frost. South or southeastern slopes are often used advantageously by early vegetable gardeners.

Large bodies of water tend to regulate the temperature due to the high specific heat of water, which is responsible for the absorption of large amounts of heat. Water reduces the amount of radiant energy reaching the soil.

Vegetative cover acts as an insulator modifying temperature changes in soils. Bare soils warm up more quickly and cool off more rapidly than those covered with vegetation. The greater the cover, the less variation there is between night and day. A cover of snow during winter prevents rapid change of temperature.

Dark colored soils absorb more heat in sunshine than do lighter ones. The high specific heat and the low conductivity of organic matter greatly influence the temperature of these soils.

#### Means of Developing and Maintaining Favorable Soil Structure

Farmers may aid in the development and maintenance of favorable soil structure by growing grasses and legumes in rotation. Crumb structure is encouraged by the physical effects of root extension and the mixing effects of soil organisms.

The maintenance of organic matter in the soil is very important especially in clay soils as proper granulation cannot be maintained without a certain amount of humus. It promotes ready air and water and lowers the plasticity and cohesion of clay soils.

Maintenance of organic matter is very important physically, chemically, and biologically for proper soil structure. The addition of organic matter is the only practical field method of improving the structure of sandy soil to increase the capacity to absorb and hold sufficient moisture and plant nutrient materials. The farmer may apply the organic matter as crops residues, green or farm manures.

Tillage operations must be carefully timed in heavy soils, if plowed too wet an unfavorable structure is sure to result and plowing too dry turns up clods that are difficult to work down into a good seed bed. It is a good practice to do fall plowing because of the favorable influence of freezing and thawing, and the slacking of clods by rains helps in the improvement of soil structure.

The removal of excess water from the soil by drainage is the most practical and important single means of favorably affecting soil temperature.

UNIT III

SOIL ORGANISMS

I. Macroorganisms

A. Animal forms

1. Rodents
2. Earthworms
3. Insects

B. Plant forms

1. Large fungi
2. Plant roots

II. Microorganisms

A. Animal forms

1. Protozoa
2. Nematodes

B. Plant forms

1. Algae
2. Fungi
3. Actinomyces
4. Bacteria

III. Bacteria which cause decay

IV. Bacteria which cause nitrification

V. Nitrogen fixation by free soil bacteria

VI. Nitrogen fixation by nodule bacteria.

## SOIL ORGANISMS

Man, animals, and higher plants are dependent upon living organisms in the soil. Without these living organisms soil would become a barren waste, and crops would not grow even with the proper proportion of soil grains, organic matter, air, and water. We shall consider two types of organisms: 1- Macroorganisms or those that may be seen with the unaided eye, and 2- Microorganisms or those that may be seen only with the aid of a microscope.

## Macroorganisms - Animal Forms

Macroorganisms include rodents, such as the mole, the prairie dog, ground squirrel, ground hog, mouse, and others. The burrowing habits of rodents result in the pulverizing and mixing of the soil. Organic matter is carried into their burrows as a supply of food and for nesting purposes. This material in time becomes mixed with the soil and becomes a part of the soil organic matter. The burrows serve to aerate and drain the soil. Rodents also bring soil up to the surface from the layers beneath.

The common earthworm is the most important macro-animal from the standpoint of amount of work done in the soil. In studies\* made by Darwin, it has been estimated that the amount of soil that passes through their bodies may amount to 15 tons of dry earth per acre annually. The earthworm's chief food is organic matter of the soil but it also takes into the digestive track the inorganic matter. This matter is subjected to the digestive juices and to the grinding action of the gizzard. Thus

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\*Darwin, Charles. The Formation of Vegetable Mold. New York, 1885.

the organic matter is broken down both chemically and mechanically to be more readily available to crops. The soil that passes through the body is ejected as "worm casts" and may be seen on the surface of heavy soils after rains.

The earthworm thrives best in a temperate climate, in heavy, moist soil reasonably well drained, supplied with organic matter and calcium. Normally the earthworm ranges in the topsoil; however, when it becomes dry the worm goes to the more moist subsoil and is less active. When it rains and the topsoil becomes moist again, they return to the topsoil and resume activities.

Relatively large amounts of organic matter are carried into the subsoil as the earthworms drag leaves and small pieces of residue into their burrows. In moving about they leave open burrows in the soil that serve as open channels for the downward passage of rain, water, and air, thus aiding in the drainage and aeration of the soil. Aeration of the soil is important for two reasons; namely, 1- To get a supply of oxygen to the plant root, and 2- To prevent a toxic effect of carbon dioxide accumulation.

Ants, slugs, larvae, and other insects function in the same way as the worms in that they act upon the organic matter, make burrows that serve as channels for the drainage of water, and the passage of air into the soil.

### Macroorganisms - Plant Forms

Large fungi aid in bringing about the first stages in the decomposition of woody matter, which is disintegrated through the growth in its tissues of the root mycelia of the fungi. The work of the decay bacteria is made easier after the large fungi break down the structure.

The roots of plants aid in the productiveness of the soil by contributing organic matter and by leaving openings in the soil, after they decay, for air and water to circulate. Deep rooted plants like clover and alfalfa have very beneficial effects on heavy soils in aiding drainage and aeration of the lower soil, due to the openings left by the decomposition of their roots. A well distributed supply of organic matter is left in the soil after each harvest by the mass of rootlets.

### Microorganisms - Animal Forms

Protozoa are all one-celled organisms, the simplest form of animal life. They are the most varied and numerous of the micro-animal population. For convenience they are divided into three groups: the amoeba, ciliates, and flagellates. Conditions which favor bacteria growth also favor the growth of protozoa. Most of the protozoa are dependent on free water for activity and the larger ciliated forms are only found under excessively wet conditions in highly fertilized soil. They appear primarily as destroyers that prey upon bacteria and on account of their activity in feeding upon other organisms, the protozoa

have been regarded as a factor in maintaining microbiological balances.

Nematodes are grouped into three classes according to their food demands:

1. Those that live on decaying organic matter.
2. Those that live on other nematodes - small earthworms and the like.
3. Parasitic, or those that live on higher plants, passing at least a part of their life cycle embedded in the tissue of plants.

The influence of nematodes on soil fertility is not yet known.

The parasites injure plants by attacking the roots and some attack other parts of the plants. Some of the more common diseases caused by soil organisms are: wilt of cotton, cowpeas, wheat, tobacco, tomatoes, and damping off of a large number of plants; also, root rot and galls.

#### Microorganisms - Plant Forms

Most algae lying on or near the surface of the soil contain chlorophyll and actually produce organic matter which becomes part of the soil supply. Certain forms obtain their energy from organic matter and exist below the A horizon where chlorophyll does not function. Algae are divided into three groups: the blue green, found in the warm climates; the green, found where it is cooler; and the diatoms, found in old gardens. Algae add organic matter to the soil, and some forms assimilate nitrates, others ammonia, and still others break down proteins.

Fungi form a group of soil organisms thread-like in structure and are largely microscopic in size. Like algae they are widely distributed in the soil, but unlike algae they must get their energy from the soil organic matter. Since they do not contain chlorophyll, they cannot manufacture their food. Molds and mushrooms are types of soil fungi that can be seen with the unaided eye. Since fungi must have oxygen, they are more plentiful in the surface soils than in the deep layers. Fungi work under soil conditions that are rather highly acid more readily than bacteria and for that reason they may contribute more than bacteria to the decomposition of organic matter in acid soils. Fungi are valuable to soil in that they decompose organic matter in such a way as to be economical in the use of carbon.

Actinomyces rank next to bacteria in numbers in the soil, ranging from hundreds of thousands to a few millions per gram of soil. They are a little larger than bacteria, less exacting in their requirements, being able to grow in drier soils, and they require less nitrogen. They are most abundant in old sod fields and hence are probably associated with the decomposition of grass roots. Actinomyces serve as decomposers of organic matter, attacking the celluloses and perhaps the more resistant soil humus making it available to higher plants. They aid in the fertility of the soil in that they set bound nitrogen free as ammonia. Actinomyces are sensitive to acidity and are nearly neutral in reaction. The application of farm manure greatly increases their numbers. The aroma of freshly plowed ground is probably due to actinomyces.

Millions of microscopic organisms live in the soil and aid in maintaining and adding to the fertility of the soil. Of these millions, the smallest of all, which are bacteria, probably play the greatest part in making possible the production of successful crops.

Bacteria are among the one-celled organisms. The majority of soil bacteria are aerobic, which means they must have abundant air to live and function. Decay of organic matter is carried on by this group. The other group of soil bacteria is known as anaerobic, which means they live in conditions where there is no free oxygen, but get their supply from the compounds of oxygen in the soil. The foul odor of peat bogs is the result of anaerobic type of fermentation. Putrefaction is produced by anaerobic bacteria; decay is produced by aerobic bacteria. Decay and putrefaction may be in process at the same time, in the same body, and in the same soil. Decay may be taking place on the outside in all places exposed to the air and putrefaction on the inside where there is little oxygen.

According to their sources of energy bacteria are divided into the following two groups:

1. The autotrophic bacteria, which obtain energy by the oxidation of inorganic material or minerals such as nitrate, ammonia, sulphur, hydrogen, and iron compounds; and,
2. The hetrotrophic bacteria, which get their energy and carbon directly from soil organic matter.

## Bacteria Which Cause Decay

One is prone to think the world would be better off if nothing ever rotted or decayed. How fortunate we would be if teeth never decayed or if buildings would last forever! On the other hand, the world would become choked with rubbish, but more important than that, the soil would become depleted of elements necessary for plant production. All plants and animals finally die and disappear, and it is through decay that they become again a part of the earth, water and gases. Many kinds of organisms take part in this work, but bacteria and fungi play a large part in decay and decomposition. All organic matter can be broken down into the elements of which it is composed. It is these changes that provide sustenance to prolong life on earth and make possible new life. Without bacteria these changes could not take place. No crop could be produced without decay. Nitrogen in the soil is held there, not in the mineral particles, but only in complex, insoluble compounds in the form of organic matter. The organic matter must first undergo decomposition.

The supply of mineral elements used by crops is secured from two sources. When nitrogen compounds in the soil organic matter pass through the changes necessary to provide available nitrogen, the mineral elements, which this organic matter contains, likewise become available. Corn, for example, secures its supply of nitrogen from one main source--the organic matter, and its supply of mineral elements from two sources--from the mineral soil particles and from organic matter.

Decay of organic matter aids decay of mineral particles. The organisms not only bring about the necessary changes in the organic matter to provide available nitrogen and mineral elements for use by plants, but in an indirect way they aid in the liberation of mineral elements contained in the mineral soil particles. This is explained through the fact that in all organic decay, acids are formed which are effective agents in dissolving mineral matter. In the process of decay of organic material, most of the carbon and hydrogen are quickly converted into carbon dioxide and water, and the nitrogen into ammonia and probably some free nitrogen. The free nitrogen is possibly due to the oxidation of ammonia.

Ammonification is the stage of the process of decomposition during which ammonia is formed from the intermediate products. Certain plants can utilize ammonium salts as a source of nitrogen while others show a preference for nitrogen in the form of nitrates. Most all plants seem to grow better if some nitrate nitrogen is available.

#### Bacteria Which Cause Nitrification

Nitrification is the decomposition of protein substances by different species of bacteria, actinomyces, fungi, and protozoa to liberate nitrogen. Bacteria is the most important agent of these groups. The fungi, actinomyces, and protozoa are relatively unimportant in nitrification. Nitrogen of soil organic matter cannot be used directly by crops, without first being changed into some readily soluble form, usually

nitrites. The steps in the process of nitrification varies with the different species and conditions under which they work. Aerobic bacteria are of major importance. With sufficient oxygen supply these bacteria break down proteins into amino acids, then to ammonia, carbon dioxide and water. Inorganic elements like sulphur are liberated as oxides. Anaerobic bacteria function under very limited conditions of oxygen supply decomposing proteins into free nitrogen, methane, and hydrogen sulfide. If the organic matter contains less than 1.5 per cent nitrogen, all the ammonia liberated during the early part of decay will be used by the microorganisms effecting its decomposition and none will be liberated for crop use.

The starches, sugars, and water soluble proteins are decomposed very rapidly while the true cellulose is much slower and the fats, oils, lignins along with the waxes and resins are very resistant and are present as a residue when the decay process begins to slow up. This persistent part of the organic matter is just as important as the more readily decomposed portion. The all important organic residue, humus, is built up from such materials. Humus is an indispensable substance in soil fertility. Without these resistant groups, organic matter would quickly disappear from most soils.

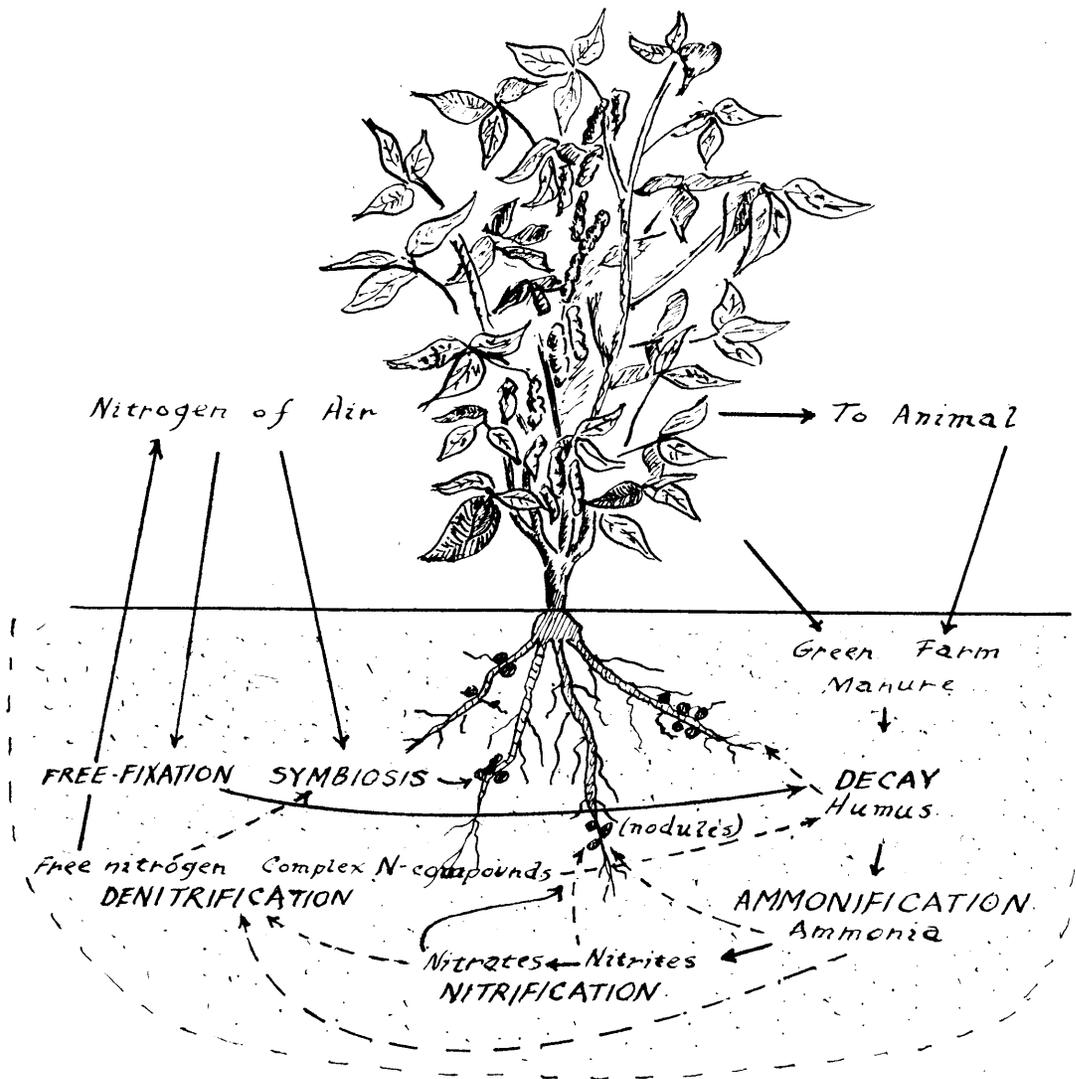
Since nitrification is a process of oxidation, any procedure that increases the aeration, such as plowing and cultivation, are recognized means of promoting nitrification. The temperature most favorable to nitrification is from 80 degrees to 90 degrees. Proper drainage is necessary for promoting nitrification. The moisture content of the

soil best suited for the growth of higher plants is considered best for nitrification. Lime stimulates nitrification in the soil. Small amounts of many kinds of salts, even the minor elements, encourage nitrification. Phosphates are especially beneficial with all types of soil organisms, as well as nitrifiers. Reasonable fertilization promotes nitrification as well as the growth of crops.

Large amounts of easily decomposed substances such as straw or coarse manure with a wide nitrogen-carbon ratio will frequently retard the growth of plants if sufficient time is not allowed for partial decomposition of the organic matter to take place before the crop is planted. The reason for this is the added carbohydrate supply is a ready source of energy for the organisms of the soil and there is a tremendous multiplication of their numbers. Nitrogen is necessary for the synthesis of the new protoplasm. The soil organisms use all the available nitrate in the soil for this process and little if any is left for the higher plants. After the organic matter becomes partially decomposed, conditions become favorable for nitrification and nitrates may again accumulate in the soil.

#### Nitrogen Fixation by Free Soil Bacteria or Non-Symbiotic Bacteria

There are bacteria in the soil which have the power of fixing bacteria or gathering nitrogen independently of any roots or higher plants. These organisms use organic matter as a source of energy and are able to obtain elemental nitrogen from the soil air. This nitrogen



A diagram of a soybean plant showing the movements of nitrogen between soil, plant, animal, and atmosphere.

is incorporated in their bodies and is left in the form of proteins and related compounds when they die. This group of bacteria is known as azotobacter and the process by which they fix nitrogen is known as azofication. Organic matter containing a high per cent of carbon, since it supplies energy readily, greatly encourages azofication. Sod land, because of the large amount of organic matter with a wide nitrogen-carbon ration, and because it is likely to be low in nitrate nitrogen, presents nearly ideal conditions for azofication. Azotobacter work to best advantage in soils that have a pH around 6. The addition of phosphate is very beneficial for their activities.

Denitrification is a term used to denote any bacterial change which results in the reduction of either nitrates, ammonia, or organic compounds to the elemental or gaseous nitrogen. Denitrification is most likely to occur when large quantities of nitrate are applied to undrained, water logged or sour land that is poorly aerated, or when excessive amounts of fresh organic manure are used with nitrates. Probably the best control of the development of gaseous nitrogen is to keep a crop on the land as much as possible, provide for adequate drainage and tillage.

#### Nitrogen Fixation by Nodule Bacteria

Legumes do not take nitrogen from the air without the association of bacteria and these bacteria do not function without the aid of legumes. The plant and bacteria must work together to perform satisfactorily the nitrogen fixing function. The host plants furnish the carbohydrates that supply energy to the nitrogen-assimilating bacteria and the bacteria in

return fixes nitrogen that is used by the plant. The amount of nitrogen gathered by red clover is referred to in the unit on green manure.

Bacteria penetrate the rootlets and stimulate the plant to produce a growth at that point. The root growths in which these bacteria live on the legumes are called nodules. Nodule organisms are also called "symbiotic bacteria". As the plant grows, the bacteria reproduce and the nodules increase in size and number. They feed upon the plant juice, getting carbohydrates and mineral food from the plant and their nitrogen from the air in the soil and combine it in a form suitable for the plant. About the time seeds form or near the maturity of the plant the nodules disappear, the bacteria returning to the soil in large numbers. They may remain for a considerable length of time before they have an opportunity to enter plants and again gather nitrogen and multiply.

The size and shape of nodules depend on the age and the species upon which they are formed. Those on red clover are relatively small, while on velvet bean they may be as large as a hulled walnut. All nodule bacteria have the same function, but different species of legumes require quite different species of nitrogen-fixing bacteria. When nodule bacteria from one variety of legume produce nodules upon another variety, and vice versa, the organisms of the two plants are said to cross inoculate. The nodule bacteria on the following legumes can grow on one as well as on another: cowpeas, common lespedeza, Korean lespedeza, kudzu bean, and lima bean.

The beneficial effects of legumes are due to the nodules on their roots. Therefore, it is very necessary that these bacteria be present in

the soil to secure a large amount of nitrogen. Usually when a certain legume has never been grown or has not been grown recently or one that will cross inoculate has not been grown, there is a lack of proper bacteria. Legume plants grow on soil not containing the necessary bacteria but do not form nodules and do not utilize atmosphere nitrogen, the result being less growth and the plant taking nitrogen out of the soil instead of adding to the supply.

Soil inoculation is the adding to the soil the necessary legume bacteria. There are several sources of legume bacteria. The bacteria seem to remain in the soil for several years and growing legumes in rotation helps to maintain bacteria population. Soils may be taken from one field where the legume is well noduleated and applied to another field upon which the same legume is to be grown. Pure culture of the bacteria applied to the seed at the time of planting, gives good results at a low cost. This practice is recommended when there is doubt as to the presence of sufficient nodule bacteria of proper kind. Fresh culture for the particular legume desired should be used.

UNIT IV

ORGANIC MATTER OF THE SOIL

- I. Organic content of the soil
  - A. Sources of organic matter
  - B. Composition of organic matter
  - C. Amounts of organic matter in the soil
  - D. Products of decomposition
- II. Factors influencing the loss of organic matter from the soil
  - A. Erosion
  - B. Burning
  - C. Decaying and leaching
  - D. Cropping
  - E. Fallowing
- III. Ways of returning organic matter to the soil
  - A. Return of crop residues
  - B. Addition of fertilizer and lime
  - C. Return of green and fresh manures
  - D. Pasturing crops
  - E. Rotation of crops
- IV. Effects of organic matter on the physical conditions and plant nutrient supply of soils
  - A. Retention of moisture
  - B. Promotion of granulation
  - C. Holds sand particles together

- D. Reduces loss by erosion
- E. Supplies nitrogen for crops
- F. Helps to raise temperature of soils
- G. Promotes biological and chemical action

## ORGANIC MATTER OF THE SOIL

## Organic Content of the Soil

Organic matter is a fundamental part of all normally productive soils under field conditions. Soil organic matter includes the dead material of both plant and animal origin. There is not true soil without organic matter, which includes the dead roots, leaves, fruits, and stems of plants; also carcasses of insects, worms, and animals; bacteria fungi, and protozoa; and many products of decomposition of the dead residues.

The original source of the soil organic matter is plant and animal tissue, the major portion of which is contributed by plants. The organic residues on the surface of virgin soils have accumulated from the above ground parts of higher plants, such as grasses and forest litter. Soil organisms and lower forms of animal life work over the material and contribute waste products and eventually their own bodies to the supply. Some of this organic matter in soluble form passes down into the soil and some is put into the soil by root extension and decay. Soil organisms also aid in mixing the material with the soil horizon. The composition of plant materials varies greatly. Straw and timothy have a very low content of nitrogen and are high in carbon. Young green clover may contain as high as five per cent nitrogen. About seventy-five percent of the average green plant tissue is water. The dry substance of succulent green manuring crops, on the average, consists of eleven per

cent carbon, ten per cent oxygen, two per cent hydrogen, and about two per cent mineral matter called ash.

The amount of organic matter in soils varies over a wide range. Some coarse, sandy soils contain only a fraction of one per cent, while swamp land may contain as high as ninety to ninety-five per cent.

How much organic matter should a soil contain is a question often asked and one that is very difficult to answer. The rate of decomposition, and the amount that is available to furnish nitrogen for maximum crop growth and sufficient organic matter to keep the soil in good physical condition are factors to be considered in determining the amount needed. Approximately four per cent is regarded as a desirable proportion of organic matter in soil of fairly high potential productivity.

Chemically, soil organic matter represents a mixture of a great many substances which can be classified into four heads; namely, 1-Carbohydrates, 2- Oils, waxes, and resins, 3- Organic acids and their salts, and 4- Nitrogenous compounds. The carbohydrates include the readily decomposed compounds, as starch and sugars, and the more stable substances, celluloses and lignins. The nitrogenous materials are very complicated and carry carbon, hydrogen, oxygen, and nitrogen, as well as the elements sulfur, iron, and phosphorus.

#### Factors Influencing the Loss of Organic Matter from Soils

When men came to the Piedmont to farm less than two centuries ago, they judged the value of the land by the type and luxuriance of the native

vegetation. Their measure of soil productivity was based upon the size and height of cane growing along streams. When they found cane more than twenty feet tall, they knew the land was fertile and built their homes. The upland slopes were forest-covered, and the soils, loamy, humus-filled, and granular, absorbed water like a sponge, filtering it slowly to streams that flowed clear and quietly. The high productivity of most virgin soils has always been associated with their high content of organic matter and the decrease in the supply has generally been closely followed by a corresponding decrease in fertility. The loss of organic matter represents soil compaction, which slows up the circulation of air and water and hinders tillage operations and at the same time disturbs the function of the soil in plant nutrition.

Organic matter may be lost from the soil in a number of ways. Erosion accounts for great losses of soil organic matter. Rain water flowing from a clean, tilled field is always muddy, laden with soil material and light weight dry fragments of organic matter floating on the surface of the water to be carried away by it.

Burning of crop residues, corn stalks and broom sedges was commonly practiced in Virginia a few years ago. Even hens nest grass and weeds, that could easily be turned under, were burned from land that was being plowed. Such wastes have greatly lowered the productivity of our soils. Burning vegetation releases the nitrogen contained in it, to go into the air with the smoke. Burning also destroys the partly decomposed plant material and organic matter that protects plant roots, holds

water and improves the physical conditions of the soil. Burning reduces the productiveness of pasture soil by oxidizing the partially decomposed organic matter and placing the minerals contained in the vegetation in a form which may be readily removed by leaching and erosion. Some beneficial effects of leaving organic matter on the soil in lieu of burning are: to retard evaporation, give protection from temperature extremes, and to make conditions favorable for the development of worms and beneficial microorganisms.

The decay of organic matter is natural and necessary if plants are to grow. In the decay of most kinds of organic matter, nitrogen is liberated as ammonia and finally into the soluble or nitrate form. If plant roots are not present to take up the nutrients, they are lost by leaching out in the drainage water. By keeping the land covered with crops, the heavy loss of nitrogen in drainage may be avoided. Cover crops are very practical for conserving the nutrients when the land is not needed for regular crop production.

Cropping speeds up the process of decay of organic matter in the soil and the crops use nutrients made available by decay from organic matter. When the crops are harvested, much of these nutrients are removed from the land. The intertilled crops, such as corn, usually use more nitrogen and more organic matter would be decomposed to produce the nitrogen. Non-tilled crops usually have a greater amount of plant roots and stubble left on the soil to aid in maintaining the supply of organic matter. The object should be to have a steady supply of organic matter undergoing decay processes for the benefit of the growing crop.

### Ways of Returning Organic Matter to the Soil

The maintenance of a proper supply of organic matter in soils is of practical importance since organic matter is a storehouse of nutrients and a regulator of their supply to growing plants, which reveals the importance of this material to the productivity of soil.

Crop residue and roots form a very large portion of the organic matter added each year to the soil and is perhaps the most important source of supply. Crop residues include the stubble and roots of such crops as small grains, hay crops, roots and stalks of corn and now with the advent of the combine, straw is returned to, and often allowed to remain on the soil. The roots are well distributed throughout the soil and stubble distributed on the surface, so when they are turned under, they make a desirable mixture uniformly distributed with the soil. The dry material of roots and stubble of cereals amount to approximately two tons per acre while the roots and stubble of red clover amount to about four tons per acre.

Regardless of the volume of crop residues left on the land, harvesting and removal of plants does deprive the soil of certain mineral nutrients supplied by the soil itself. Lime should be added if basic materials are lacking, for it promotes bacterial activity as well as plant growth. The addition of fertilizers where ever soils are deficient in one or more of the important plant nutrient elements may be expected to increase crop yield and at the same time, the plant is producing a large root system and a larger growth of stubble that is left on the land.

The organic matter of the soil may be increased naturally by plowing under green crops. This is a very satisfactory practice when it can be accommodated to the rotation. Such crops as rye, clover, peas, beans, and vetch as well as others, may be used. All of these increase the organic matter of the soil, and by using legumes, not only is the organic matter increased but the nitrogen supply is also increased if the legume is properly inoculated.

Farm manure is valuable because of both the organic matter and nitrogen supply present. Its use, in general, favors the upkeep of organic matter in the soil.

The pasturing of certain crops on the farm has advantages of saving labor and distributing manure fairly evenly over the grazed area. More of the dry matter eaten as green pasture grasses is returned to the soil, in the form of plant nutrients, than is usually returned from feeding hay and grain, due to the losses that usually occur, in the latter, between its production and its return to the soil.

A rotation that furnishes a sod crop helps to maintain the organic matter supply of the soil and furnishes raw food material for soil bacteria. Crop rotation not only tends to favor higher crop production, but usually results in better crop quality than continuous cropping. The use of legumes in rotation aid in maintaining both nitrogen supply and organic matter. Good soil management seeks to adjust the addition of organic matter, the physical and chemical conditions of the soil, and losses through biological activities in such a way that paying crops may be harvested without reducing the organic supply of the soil below the point where successful crops can be produced.

Fallowing means leaving the land without a crop for a season. The objects of fallowing were to destroy weeds and to increase the moisture content of the soil in dry areas. The practice of fallowing has resulted in the loss of much soluble plant food which was produced by the decomposition of organic matter. Heavy winter and spring rains caused much of this organic matter to be leached out of the soil and lost.

#### Effects of Organic Matter on the Physical Condition and Plant Nutrient Supply of the Soil

Fresh organic matter absorbs water and holds it as does a sponge; often it is capable of holding several times its own weight in water. Then a soil rich in organic matter usually possesses a high water holding power. Alternate wetting and drying and freezing and thawing of organic matter bring about great volume changes which greatly promotes granulation. The organic matter tends also to spread the individual particles of soil farther apart, and this loosening effect is very desirable in clay soils. Thus, the formation of granular structure most favorable for the development of crop plants is governed by the content of humus in the soil. The better tilth induced by the presence of organic matter in any soil tends to promote ease in drainage and to encourage good aeration.

In sandy soils the smaller the pieces of organic material occupy the large spaces between the sand particles and because organic matter has a higher cohesive and adhesive power than sand, it performs the

function of a binding material with the soil. This condition greatly increases the water holding capacity of loose textured soils and aids in resisting drought.

The amount of erosion by water is influenced by the texture, structure, and organic matter content of the soil. Organic matter by increasing granulation aids in the downward movement of water into the soil; therefore, it may reduce loss of water by runoff and erosion. Fibrous organic matter of roots and stem material plowed under helps to hold the soil together mechanically, thereby checking erosion.

Bacteria and other soil organisms are furnished a source of energy by organic matter and the production of carbon dioxide is greatly increased by its presence. Carbon dioxide as well as other acids generated aid the capacity of the soil water as a solvent agent and greatly increases the amount of mineral plant food available to the crop. Black color imparted by humus tends to raise the absorptive power of the soil for heat. Crops germinate and make more rapid growth on the dark than on the light colored soils even though drainage and other physical properties are similar.

Good soil management of the rotation requires frequent returns of organic matter in order to maintain the productivity of the soil, and furnish a plentiful supply of nitrogen.

UNIT V

SOIL WATER

I. Why plants require water

- A. Nutrient
- B. Absorptive power
- C. Transportation
- D. Turgidity
- E. Cooling agent
- F. Physical and chemical changes
- G. Solvent

II. Factors influencing the water requirements of plants

- A. Weather
- B. Water supply in the soil
- C. Fertilizer and manure

III. Forms of soil water

- A. Gravitational water
- B. Hyroscopic water
- C. Capillary water

IV. Movement of soil water

- A. Transpiration
- B. Evaporation
- C. Run off
- D. Percolation

## SOIL WATER

The soil, in order to serve the purpose as a medium for plant growth, must contain a certain amount of water. This water is necessary to carry on chemical, physical, and biological activities of the soil, dissolve nutrients and transport them to the plant, and water is itself a vital part of plant growth. Water has an important position in relation to the plant and has movement which greatly determines its usefulness to the plant.

## Why Plants Require Water

Water is a plant nutrient and in its natural state may become a part of the plant cell. Water absorbs valuable plant elements into solution and transports these nutrients to plant cells by different forms of plant action such as osmosis and capillary action. Water maintains turgidity of the plant cells or keeps the cells as round or as full as possible. This process prevents wilting. Water acts as a cooling agent. When cells transpire, a cooling effect upon the leaves and stems is maintained. Water aids in physical and chemical changes within the plant. The greatest importance of water is to act as a solvent and without water chemical changes in the soil are at a minimum. Chemical reactions are a prerequisite for plant and animal growth.

## Factors Influencing the Water Requirements of Plants

Weather, water supply in the soil, fertilizer and manure, and the quality of the soil influence the water requirements of plants. Hot and

dry climates necessitate the requirements of water to a much greater extent than cool moist climates. With wind and sunshine in abundance, much water is transpired, which further influences the requirements of plants for water. When plenty of water is available in the soil, plants naturally use up as much as they can but when drought occurs, plants have to go deeper to secure water for growth. Fertilizers and manure upon the soil will reduce the amount of water necessary to grow a crop, because the correct amount of organic matter in the soil helps to conserve water. A soil rich in plant nutrients decreases the amount of water needed for growth of the plant.

#### Forms of Soil Water

There are three forms of soil water which may occur in soil--gravitational, hyroscopic, and capillary. Gravitational or free water will run off or flow because of the pull or gravity. Hyroscopic water is that small amount of water which forms a thin film around the soil particle. It is not free to move at all and therefore is not used by the plant.

Capillary water is the water that is left after free water has run off but it is free to move from soil particle to soil particle. Capillary water forms a film around the hyroscopic water and the soil. Free or gravitational water is available to the plant for only a limited time and hyroscopic water is not available at all, so this leaves capillary water as the most important form of water to the plant.

Capillary water acts as a reserve from which plants draw their water requirements. There are three means in which soils hold capillary water:

1. In form of films around the soil particles,
2. In the organic matter as a sponge, and
3. In the open or pore spaces within soil granules.

The capillary water is the only form of water bearing nutrients in solution that remains in the soil for a considerable length of time, if drainage is satisfactory; therefore, it functions in chemical and physical ways to the extent that it is called soil solution. Organic matter added to a sandy soil makes more capillary water available to the plant and therefore should increase the value of such land for crop production.

#### Movements of Soil Water

There are four important movements of soil water; namely: transpiration, evaporation, runoff, and percolation.

Transpiration is the process by which soil water is lost through the leaves of plants by the effect of sunshine and wind. This loss is so great that it is often difficult to maintain an adequate supply of moisture in the soil during the growing season. "Water requirement" or transpiration ratio is the pounds of water transpired for every pound of dry matter produced.

Evaporation is the process by which water is lost from the surface of the soil. In some soils capillarity moves the water to the surface and

causes it to be lost by evaporation. Practically all evaporation takes place at the surface of the soil. The loss of moisture by evaporation in drought periods, especially if high temperature prevails, is very serious and often a deciding factor in crop yields. One method of checking evaporation losses at the surface is by the means of mulches of straw, manure or leaves. Soil mulches help retain moisture in the soil by preventing rapid rise of moisture by capillarity action. Soil mulch is obtained by light cultivation two or three inches deep and its function is to shut off capillarity movement upward.

Run-off is the manner of loss due to rain falling at a faster rate than the absorptive power of the soil. This is an entire loss to the crop and also removes valuable elements essential to plant growth. Run-off occurs when rain falls faster than the soil can absorb it. The amount of water lost by this method varies with the intensity of rainfall, the topography and condition of the soil. Surface run-off is of no value to the plant and sometimes causes serious erosion, especially on bare or cultivated land. In such cases, it carries away plant nutrients, organic matter, and some of the surface soil. Loss of water by this method can be reduced by following a number of practices. Some of these practices are listed:

1. By fall plowing.
2. By loosening up any hard and compact soil and subsoil.
3. By plowing and cultivating on the contour.
4. By strip cropping.

5. By adding organic matter.

6. By providing cover crops such as legumes, grasses and small grain.

In fact, any one or a combination of these methods may be used to reduce and control run-off that may aid the soil in trapping and storing water.

Percolation is the passing of free water straight down through the soil. This occurs when the amount of rainfall entering the soil becomes greater than the water-holding capacity of the soil. The quantity of water entering a soil is determined by the physical condition of the soil. When the soil is hard, compact, and impervious, most of the rainfall runs off and considerable erosion may result as well as the serious loss of water. Water enters readily in loose, open soil and little is lost in surface run-off. Percolation takes place so rapidly in sandy soils that they fail to hold sufficient water for many crops. If the capillary action of the soil is high, less of the water is lost by percolation.

Percolation removes the soluble salts of the soil, especially lime, potassium, and magnesium but little of the phosphorus is lost due to the small amount in the soil and the tenacity with which it is held in the soil. The loss by percolation is dependent upon the amount of rainfall and the water-holding capacity of the soil. The water-holding capacity may be increased by the addition of organic matter to the soil. Compact-  
ing light soils may help by reducing the size of the openings between the

soil particles. Percolation is desirable in soils with the proper physical make up as such soils retain sufficient water in the surface and subsoil for use by crops. Losses by percolation are reduced by cropping land. When percolation is too slow, free water which is highly unfavorable for most crops, remains in the soil and the soil becomes water logged. This condition may be overcome through encouraging percolation by land drainage.

The bad effects of percolation are the actual loss of water and the leaching-out of mineral salts that may be necessary for plant food.

UNIT VI

SOIL TILLAGE

I. The meaning of tillage and tilth

II. Reasons for tilling soil

- A. To loosen and pulverize the soil
- B. To turn under coarse litter and vegetation
- C. To control weeds
- D. To conserve moisture
- E. Aeration of the soil

III. Plowing

- A. Plow at the proper time
- B. Plow to the proper depth
- C. Plow under organic matter

IV. Preparing the seed bed

- A. Purpose of a good seed bed
- B. Harrowing
- C. Compacting

V. Cultivating the crop

- A. Purpose of cultivation
- B. Time of cultivation
- C. Depth of cultivation
- D. Frequency of cultivation

## SOIL TILLAGE

## The Meaning of Tillage and Tilth

Tillage is the working of the soil by means of implements for the purpose of bringing about more favorable conditions for plant growth. Tillage includes all the ways of loosening, turning, stirring, and compacting the soil. The most common operations of tillage include plowing, harrowing, rolling, and cultivating the growing crop.

Tillage is necessary for good tilth. Good tilth is defined as that physical condition of the seed bed with respect to mellowness and firmness that is favorable to plant growth.

The main expense item in the production of crops is tillage. However, good soil tillage economically performed is an absolute essential for profitable farming.

## Reasons for Tilling the Soil

Loosening and pulverizing soils are necessary for the efficient growth of all ordinary crop plants. Covering of crop remains is important for several reasons. First, trash interferes with the preparation for and the cultivation of crops; second, coarse material decays very slowly when left on the surface, due to lack of activity of organisms; and third, complete coverage aids in the control of insect pests.

All types of tillage aid in the control of weeds. Weeds take plant nutrients and moisture that may otherwise be available to crops and may cause injury to some crops by shading.

Loose soils take up and absorb water more rapidly than do compact soils. Cultivation increases the water supply by reducing surface runoff and by killing weeds. By retaining the water in the soils, the organic matter and plant nutrients are saved.

A well aerated soil is necessary for proper functioning and growth of favorable bacteria in the soil. Oxygen is needed for seed germination and root growth. Oxygen and carbon dioxide are both necessary in the soil for certain chemical changes that make plant nutrients available.

### Plowing

Plowing usually is the first tillage operation. It provides for the loosening of the soil and the incorporation of organic matter to the soil. Plowing is the practice of cutting the surface soil into thin slices and depositing it into more or less broken parts in a partly inverted position. The furrow slice is the portion moved by the plow and may vary in width according to the size and set of the plow. It is a common practice to plow small fields by starting on one corner and plowing around the entire field throwing the furrow slices out. The resulting double width furrow thrown in opposite directions in the center is called a dead furrow. In most large level fields plowing is usually done in strips called lands. A back furrow is used whereby two adjoining furrow slices are thrown together from opposite directions to form a ridge. Care should be taken to lay out the strips straight and parallel. When

the plowing is completed, the field will have alternate dead and back furrows across the field. The next time the field is plowed, back furrows should be located where the dead furrows formerly were and vice versa. When it is necessary to cultivate land subject to erosion, it should be plowed on contour.

The two common types of plows used are the moldboard and disk plow. Both have their advantages under certain conditions. The moldboard plow is generally recognized as the most satisfactory for plowing ordinary soils. The moldboard will not scour in dry and hard sticky soils. These soils can only be plowed successfully with a disk plow.

The best time to plow depends upon the conditions. Usually it is a good practice to do late fall plowing while work is slack to relieve the pressing work in the spring. This is especially important where the labor supply is limited.

Generally, sod land should be plowed in the fall. The coarse litter and roots turned under have time to partially decompose, forming a better contact between the seed bed and the subsoil, and providing a better supply of available plant food elements by mid-summer. In heavy soils plowed in the fall, freezing and thawing favors a crumbly structure and many crop insects and pests, and weeds are destroyed. Soils may be plowed wetter in the fall than is advisable in the spring. Fall plowed land should be left rough during the winter as it aids in collecting an increased supply of water for the spring crops and will be less subject to erosion.

Often, time does not permit plowing in the fall. Clay soils have a narrow moisture range for plowing and there is danger of plowing the heavier soils too wet in the spring.

Spring plowing is preferred when winters are mild and the soil is subject to leaching or where erosion may become a serious problem. Late spring plowing permits turning under of green manure crops which ordinarily do not make sufficient growth for fall plowing. Crimson clover and rye are good examples of green manure crops that are turned under by late spring plowing. When choosing between fall and winter plowing, one should consider all the factors from the standpoint of the individual farm. It is wise to follow the practices of the successful farmers of the community.

As a rule, best results are secured when soils are plowed moderately deep, usually 6 to 8 inches. Increasing the depth greatly increases the cost of plowing. Varying the depth of plowing from year to year to prevent compacting the soil at the bottom of the furrow is a good practice.

A subsoil plow is sometimes used when the subsoil is so compact that water and roots cannot penetrate. This implement follows the plow and cuts a thin gash in the subsoil 6 to 10 inches deep without throwing it to the surface. Results seldom warrant the extra expenses.

Plowing is a means of adding organic matter to the soil. Crop residues, green manures, farm manures, and seed crops are materials that are plowed under to furnish organic matter to the soil. Organic matter should be plowed into rather than under the surface soil.

### Preparation of the Seed Bed

A mellow and firm seed bed is necessary for favorable germination and for the production of strong root systems in young plants. It is necessary for soil particles to be in close contact with each other and between the seed bed and the subsoil in order to have the proper capillary water moisture for seed germination. Proper seed bed preparation brings about the above conditions in addition to destroying the weeds.

The purpose of harrowing is to level the plowed soil, make firm and compact the seed bed and to destroy weed seedlings. The disk harrow is probably the most useful of all harrows, ranking next to the plow in seed bed preparation. The disk harrow pulverizes lumps, packs the soil, mixes organic matter throughout the seed bed, bringing plant food elements together to form useful compounds, and reduces large air spaces to help form the seed bed.

Frequently, a disk harrow is all that is required to prepare a good seed bed for small grain. The spring tooth harrow is a very efficient tool on rough and stony ground and is used instead of the disk harrow to loosen and pulverize the soil.

The spike tooth harrow is a very effective implement in fining and smoothing the immediate surface of the plowed soil and is especially useful for putting the finishing touches on seed bed preparation. It is also very effective in killing small weeds in crops such as corn that is not yet large enough for cultivation.

There are several kinds of rollers used, the cultipacker probably being the most valuable, for breaking clods and compacting seed beds that are too loose or do not have sufficient contact with the subsurface soil. The cultipacker firms the seed bed, yet the surface is in fairly loose condition, and as a result a crust is less likely to form on the surface.

### Cultivating the Crop

Cultivation or intertillage means the stirring of the surface soil between the rows of crops by various types of cultivations.

The purposes of cultivation are to kill weeds, to conserve moisture, and to aerate the soil. The first and by far the most important objective in cultivation is to kill weeds. Weeds compete with crops for food, water and sunlight, and without proper weed control serious damage or crop failure results. The economic production of practically all crops depends on controlling weeds. The best time to kill weeds is when they are small. Cultivation kills weeds in three ways: 1- The roots of weeds may be loosened and exposed to the drying sun; 2- They may be covered and smothered with soil; or 3- They may be cut off or covered with soil to prevent their manufacturing food.

A good way to have successful cultivation is never permit weeds to get a start. Data from Illinois Experiment Station in a six year test showed corn in which weeds were allowed to grow produced 7 bushels per acre, and 45 bushels were produced on the plot which was given three

shallow cultivations. Time of cultivation and the number of cultivations necessary for a crop will depend largely upon the season.

Usually, best results are secured when cultivated crops are given shallow cultivation. Deep cultivation, particularly after the plants have considerable root spread, tends to cut off crop roots, reducing the feeding capacity of the plant. Shallow cultivation seems to be efficient in conserving water, aerating the soil and killing weeds. Nothing is gained by going deeper than is absolutely necessary to kill weeds. In general, it is best to practice level cultivation except under certain soil conditions.

The frequency of cultivation depends largely on weed control. Efficiency, rather than frequency, should be the objective in cultivation. If weeds are properly controlled prior to and immediately following planting, three cultivations will usually be sufficient.

UNIT VII

CROP ROTATION

I. Reasons for crop rotation

- A. Keeps the soil in suitable physical condition
- B. Helps to maintain the supply of organic matter and nitrogen in the soil.
- C. Provides a practical means of utilizing farm manure and fertilizer
- D. Improves distribution of root systems of crops
- E. Provides for a balanced removal of plant foods
- F. Helps to control weeds, insects, and disease
- G. Counteracts the development of toxic substances
- H. Improves the yield and quality of crops
- I. Keeps the land occupied with crops a greater part of the time.
- J. Systematizes and diversifies farming
- K. Saves labor

II. Essentials of a good rotation

- A. Crops adapted to soil and climate
- B. Crop acreage the same each year
- C. Feed and bedding provided for livestock
- D. A cultivated crop for weed control
- E. One or more cash crops
- F. A legume crop every three to five years

G. Sod crop desirable in a rotation

H. Catch and cover crops should be used where practical

I. Erosion control should be provided

### III. Planning the rotation

## CROP ROTATION

Crop rotation is a system of growing different kinds of crops in recurring succession on the same land, over a period of years.

## Reasons for Crop Rotation

## Improve the Physical Condition of the Soil

When the same crop is grown continuously on the land, there is a rapid loss of organic matter from the soil, which has a decidedly bad effect on the physical condition of the soil. As organic matter is lost from sandy soils, they become looser and more subject to erosion while clay soils lose their crumb structure, become more difficult to cultivate and percolation, aeration, and nitrification are retarded. Small grains, grasses, and legumes produce root systems that aid in the production of a granular condition that greatly improves the physical characteristics of the soil.

## Organic Matter and Nitrogen

Cultivated crops tend to deplete the soil of organic matter. The growing of legumes tends to build up organic matter and supply nitrogen to the soil. A rotation which includes a sod crop helps to maintain the organic matter supply as well as furnish raw material for beneficial soil bacteria. These bacteria in turn are important agents in making the minerals of the soil soluble.

## Utilizing Farm Manures and Fertilizer

A well planned crop rotation makes practicable the application of

manure and fertilizer to the most responsive crops and those of high cash value. Corn is a gross feeder, and in a rotation of corn, wheat and mixed hay, manure would be applied to the corn land. Or if manure is lacking, the fertilizer is best applied to corn and wheat and the hay will use any residual fertilizer.

#### Distribution of Root Systems of Crops

Crops vary in the depth of their root systems. Small grains are shallow-rooted crops and draw their supply of nutrients from near the surface of the soil. Corn, clover, and alfalfa are deep-rooted crops and they get their nutrients from a lower feeding zone.

To provide for a change in location of the feeding range of plant roots, it is a good practice to alternate shallow and deep-rooted crops. Since shallow-rooted crops tend to deplete the nutrients in the immediate surface soil, it is desirable that deep-rooted plants follow shallow-rooted crops. Deep root penetration not only obtains nutrients from the lower zone but provides better drainages and root residues decay and help maintain the organic matter.

#### Balanced Removal of Plant Food

The plant food requirements vary with different crops and by rotating the crops, the different plant nutrient materials may be removed from the soil in a more desirable proportion.

#### Control of Weeds, Insects, Pests and Disease

Certain weeds grow well in association with certain crops but no

with others. For example, wild onions and ragweed thrive in fields of small grain; oxeye daisy, plantain occur in hay fields; the morning glory and pig weed are typical of corn fields. Since most weeds are annuals unable to sprout from their roots, and depend upon their seed for reproduction, cultivation will tend to kill the early maturing weeds while cutting hay and small grain before the weed seed are ripe will destroy many other obnoxious weeds.

Rotating crops is an effective method of reducing the damages done by many insects and diseases since many of them attack only one plant or group of plants and when the same crop is grown every year, insects and disease accumulate to such a point that production is unprofitable. Potato scab may become serious if the potato crop is grown on the same land continuously. This and many other plant diseases are checked or controlled by a proper rotation.

#### Counteracts the Development of Toxic Substances

Certain organic toxic compounds may result from improper decomposition of soil organic matter when the same crop is grown year after year. Crop rotation insures normal decomposition processes and affords an economical means of preventing the formation and accumulation of injurious substances in the soil.

#### Improves the Yield and Quality of Crops

Rotation of crops usually increases crop yields and as a rule insures better crop quality than does continuous cropping. The fact that

the destruction by insects and plant diseases is reduced to a minimum in a crop rotation system compared with continuous cropping is conducive to better crop quality.

Effects of Growing Crops Continuously and in  
Rotation, 1917 to 1926, inclusive

Crop		Rotation		Continuous Cropping	
		No Fertilizer	Fertilizer	No Fertilizer	Fertilizer
Corn	Bushels	57.50	34.67	32.48	19.91
	Pounds of grain per pound of stover	.98	.86	.85	.71
Wheat	Bushels	23.39	7.41	20.05	8.63
	Pounds of grain per pound of straw	.48	.42	.60	.50
Hay	Tons	1.86	.89	2.23	1.10

\*T. K. Wolfe and M. S. Kipps. The Effects of Rotations, Fertilizer, Lime and Organic Matter on the Production of Corn, Wheat and Hay. Bul. 253, Va. Agri. Exp. Sta., V. P. I., 1927.

The above table shows the average yield per acre of corn, wheat, and hay when grown in a four-year rotation and when grown continuously on the same land with and without fertilizer. Both the continuous cropping and rotation experiments received applications of ground limestone in the spring of 1922 at the rate of two tons per acre.

Wolfe and Kipps stated corn in rotation without fertilizer and manure gave as good results as corn growing under continuous cropping conditions

with fertilizer and manure. Wheat yields were not influenced to the same extent as corn.

When compared with continuous cropping a rotation system helps to maintain soil fertility and frequently increases it, but it should not be depended upon entirely to do so. By intelligently combining the use of rotation and a sufficient supply of fertilizer and manure, best results have been obtained and soil fertility is maintained at a high level. When a good rotation coupled with a definite plan of fertilizing is put into practice, crops are grown more profitable than on a one crop system.

#### Rotation Keeps the Land Occupied with Crops

A well planned rotation makes it possible to have the land occupied with a suitable crop most of the year. Keeping the ground covered with a suitable crop reduces the loss of plant food by leaching to a minimum and losses from soil erosion are greatly reduced as compared with bareland.

#### Farming Systematized and Diversified

Diversification is accomplished best through crop rotation as it usually provides means for maintaining soil fertility. It generally pays a farmer better to have several important products than just one product because diversification provides for the following:

1. Provides against total failure due to weather, pests, and prices, as all these hazards are not likely to hit several crops in one year.
2. Crop rotation distributes labor throughout the year. Full

employment all through the year for men and teams is usually essential for farm success.

3. Distributes the income over the year.
4. Crop rotation simplifies the farm layout and reduces the number of fields.
5. It enables the farmer to estimate ahead of time the amount of labor, seed and the power machinery necessary for the operation of the farm

#### Saves Labor

Crop rotation makes possible the growing of two or more crops after one plowing. Where a rotation of corn, wheat, clover and grass is practiced, the land is plowed for corn, the corn stubble is disked for wheat, and the clover and grass are seeded in the wheat without further preparation, except possible harrowing when clover is seeded in the spring.

#### Essentials of a Good Rotation

1. Field crops grown in rotation should be adapted to the soil and climatic conditions.
2. Uniform acreage of crops each year.
3. The rotation should provide feed and bedding for animals kept.
4. The rotation should include one cultivated crop for controlling weeds.
5. The rotation should include one or more cash crops.

6. A legume soil-improving crop should be included every three to five years.
7. It is desirable that the rotation include a sod crop, either legume grass or a combination of the two.
8. Catch crops and cover crops should be used where it is practical.
9. Rotation should be so arranged as to use such devices as terracing, strip cropping and contour farming to control erosion.

#### Planning the Rotation

In setting up a rotation it is essential to utilize crops that are adapted to the local soil, climate, and market conditions and use those crops that fit into the system of farming. Carefully consider the cropping systems used by the best farmers in the community when planning a rotation. Rotation to be most beneficial should include the proper combination of crops in the proper order of cropping.

Usually a rotation should include three types of crops: a cultivated crop, a small grain crop and a hay crop, in the order named. The cultivated crop aids in weed control and prepares the land for small grain without additional plowing. Legumes and grasses are seeded in or following the small grains with little or no additional cost for seedbed preparation. The small grains serve as a cover crop for the grass and legume seeding and full utilization is made of the land during the time required for the seeding to become established for use as hay. In the bright tobacco sections it is usually advisable to use one rotation for tobacco and another for food and feed, as high quality tobacco seldom grows on soils

of high productivity that is built up by the use of legumes and farm manure. Crop rotations alone will not maintain fertility indefinitely even though legumes are included. Productivity may be maintained and improved when a carefully planned rotation is established which provides a definite plan for the use of lime, manure, legumes and special fertilizers.

UNIT VIII

PLANT FOOD ELEMENTS

I. Plant food elements derived from the air and water

- A. Carbon
- B. Oxygen
- C. Hydrogen
- D. Nitrogen

II. Nitrogen

- A. Sources
- B. Availability
- C. Functions
- D. Deficiency signs

III. Phosphorus

- A. Sources
- B. Availability
- C. Functions
- D. Deficiency signs

IV. Potassium

- A. Sources
- B. Availability
- C. Functions
- D. Deficiency signs

V. Secondary plant foods

- A. Calcium

B. Magnesium

C. Sulphur

VI. Minor plant food

A. Iron

B. Manganese

C. Copper

D. Zinc

E. Boron

F. Silicon

G. Sodium

H. Chlorine

I. Iodine

VII. Hot plant foods are lost from the soil

## PLANT FOOD ELEMENTS

Plants must have sufficient food elements in the right proportions before they can grow normally and produce profitable yields of high quality. Plants to be properly fed must have all the essential plant food elements; one cannot take the place of another regardless of how small a quantity is needed if the plant is to make maximum growth and strength.

Growing plants obtain energy from the sun and food from the soil, water, and air, and convert these materials into food, clothing, and shelter for man and beast. The sun is the ultimate source of energy and green plants utilize this energy by a process known as photosynthesis.

## Plant Food Elements Derived from the Air and Water

Carbon, hydrogen, and oxygen account for a large part of organic plant material and make up 90 per cent of the total weight of the plant. These essential plant elements are obtained from the air and water. The other elements are obtained from the soil by the roots and make up less than 10 per cent by weight of the plant composition. These last elements are the main components of plant ash.

Nitrogen is absolutely essential for the growth and reproduction of both plants and animals and for the maintenance of soil fertility. Three-fourths of the entire atmosphere is nitrogen. It can be secured from the atmosphere by growing clover and other legumes.

## Nitrogen

The commercial sources of nitrogen are obtained from: 1- Inorganic or mineral (comes from the earth), 2- Manufactured from the air, 3- Chemical process, and 4- Organic matter (either animal or vegetable).

Nitrate of soda is obtained from deposits in Chile and from synthetic nitrogen plants in Hopewell, Virginia, and other factories in this country. It contains about 16 per cent nitrogen which is almost immediately available. Cyanamide is a synthetic material made up of nitrogen and lime, about 21 per cent being nitrogen. Calcium cyanamide carries an equivalent of 1500 pounds of hydrated lime in every ton and is strongly basic in reaction. Sulfate of ammonia contain 21 per cent nitrogen and is obtained as a by-product from coke ovens in the steel manufacturing districts of the United States and from other manufacturers in this country and abroad. This form of nitrogen is available almost immediately and is strongly acid.

Bone, blood, and tankage from slaughter and meat packing houses in this country and South America are sources of nitrogen. The availability of nitrogen from these sources is relatively slow, furnishing a regular supply throughout the growing season. Dried fish scraps from fish reduction plants along the coast contain from 6 to 8 per cent nitrogen and from 8 to 13 per cent phosphoric acid. Cotton seed, soybean, and peanut meal are seldom used in fertilizers at the present time due to their high feeding value to livestock.

The growing of legumes and the addition of barnyard manure are the most economical means for decreasing the need for buying nitrogen in fertilizers.

Nitrogen produces rapid early growth, promotes leaf and stem development, gives dark green color to plants and helps to maintain the proper balance between phosphorus and potassium.

Plant characteristics which may indicate nitrogen deficiency are slow growth, plants appear stunted and pale green or yellowish leaves and the plants mature prematurely.

When excessive amounts of nitrogen are present, it delays maturity, lowers the quality, and produces too great a proportion of stem and leaf to the fruit or grain. It also causes small grains to lodge badly and becomes less resistant to rust when excessive amounts of nitrogen are present.

#### Phosphorus

Low crop production is due more often to lack of phosphorus than to the lack of any other element; for this reason, it is sometimes called the master key to agriculture. This element is found in every living cell and is necessary for both animal and plant nutrition. In animals phosphorus is found concentrated largely in skeleton or bone, while in plants the largest concentrations are in the seed. Animals fed on plants grown on soils low in available phosphorus grow poorly and develop diseases that can be corrected only by the addition of phosphorus to their diet. All soils contain some phosphorus, but the supply in much land that has been cropped for a number of years is rapidly lessening.

Deposits of phosphates of economic importance have been found on every continent in the world. In the United States raw rock phosphate containing 25 to 32 per cent phosphoric acid are found chiefly in Florida, Tennessee, and the Carolinas. This form of phosphate is very slow in availability and should be applied in connection with organic matter when it is used.

Bone meal contains 20 to 25 per cent phosphoric acid and 3 to 5 per cent nitrogen and is obtained from crushed or ground bone. All of it available in three to five years.

Basic slag contains from 16 to 20 per cent phosphoric acid and is obtained as a by-product of the manufacture of steel from pig iron. Since it is so very slow in availability, it is seldom practical to buy unless it can be bought cheaply. Superphosphate carries from 16 to 45 per cent phosphoric acid. Superphosphate is made by mixing ground phosphate rock with sulphuric acid. Great care in manufacturing is necessary to insure good drilling qualities. Superphosphate has proved the most effective carrier of phosphorus in proportion to the cost. Meta-phosphate is a high concentration phosphate that contains 63 per cent of phosphoric acid. Phosphorus in gaseous form is brought in contact with rock phosphates at temperatures of about 1200 degrees centigrade to form metaphosphate.

From unpublished data secured from the state AAA office 36,598 farms in Virginia used the equivalent of 128,230 tons of 20 per cent superphosphate on 640,000 acres in 1945. This amount includes the

superphosphate secured through the AAA or purchased by the farmer in the AAA program but does not include the phosphate used in mixed fertilizer.

Phosphoric acid stimulates early root growth, strengthens the stems of plants, hastens the maturity of crops, is especially important in seed formation as it increases the ratio of grain or fruit to stalks, and helps to increase the resistance to disease.

Deficiency of phosphorus is indicated by purple stems and branches, slender stalks with few lateral leaves, too small a proportion of grain to straw and slow rate of maturity.

#### Potassium

Potassium is essential to the formation of starch, sugar, and cellulose; plants do not mature well when the supply is inadequate. Clay soils, high in organic matter content, seldom require large applications of potash fertilizers. However, sandy soils nearly always produce their greatest yield of crops where liberal applications of potash fertilizers have been made. Crops consume large amounts of potassium in growth and when crop after crop is produced on the same soil and sold away from the soil in the form of grain or livestock, the supply of available potassium is gradually reduced. A large percentage of potash used on field crops in this country is applied to cotton, potatoes, and tobacco. Due to the fact these crops are usually grown on soils deficient in potash, they require the addition of fairly

large amounts. Potash is applied to truck and vegetable crops in large amounts since they are often grown on sandy soils very low in potash content. Fertilization over a period of years seldom builds up a reserve of potash on sandy soil due to heavy leaching. The application of potash to pasture tends to increase the clover content.

Until recently practically all of our potash was imported from Germany and France. Deposits have been found in Texas, New Mexico and other Rocky Mountain states. Muriate of potash contains about 48 to 53 per cent potash. It contains chlorine and a considerable amount of common salt. Its use on tobacco and beets should be restricted because of the chlorine content.

Sulphate of ammonia contains about the same amount of potash as muriate contains and both forms are readily available. For a few crops it is preferred over the muriate form. Kainit and manure salts contain 12 to 20 per cent potash. Wood ashes contain about 6 per cent potash and are a minor source of potash.

Potassium is essential for production of sugars, starches, and oils; gives vigor to plants; helps to resist disease; strengthens stems; and improves the quality of the yield by increasing the plumpness of grain cereals.

Indications of potash deficiency are: mottling, spotting, streaking or curling of lower leaves, particularly between the veins and along the margin, slender stalks, slender roots, the early ripening or dying of stems and leaves of plants while the seeds or fruit are immature. Marginal leaf scorch and a tendency toward early loss of leaves are the most common signs in cases of extreme deficiency.

## Secondary Plant Foods

Calcium, sulphur, and magnesium are called secondary plant foods and are needed in relatively large quantities. Formerly, these elements were believed to be present in the soil in sufficient amounts or supplied in adequate amounts in ordinary fertilizer.

Tests have shown most soils in Virginia need calcium and provision for its application is essential for profitable yields. Calcium improves general plant vigor, encourages grain and seed production, neutralizes poisons produced in the plant, promotes early root formation and growth, and regulates the uptake of other plant foods. Plant characteristics which may indicate calcium deficiency are short and much branched roots and short, stunted growth.

In the Coastal Plain section of some of the southeastern states and on the Durham soil series of the Piedmont Plateau, many soils are so deficient in magnesium that magnesium deficiencies symptoms appear in many crops. On such soils, fertilizers containing magnesium should be applied. Some of the materials carrying magnesium which may be applied to the soil are: potassium, magnesium sulphate, dolomitic limestones, magnesium sulphate, magnesium limestones. Nearly all calcium limestones carry varying amounts of magnesium. Dolomitic limestone sold for agricultural lime, often carries from 20 to 30 per cent magnesium oxides. Magnesium is essential in maintaining dark green color of leaves as it functions in the synthesis of chlorophyll, promotes the formation of fats and oils, acts as a carrier of phosphoric acid in the plant, and regulates the uptake of other plant foods, especially calcium. Magnesium deficiencies

may be indicated by mottled or streaked lower leaves, leaves, leaves having a tendency to curve upward along their edges, slender stalks, and long roots with few branches.

Sulphur is an essential element for plant growth. Sulphur gives increased root growth, helps maintain dark green color, promotes nodule formation on legumes, and stimulates more vigorous plant growth. In some instances where sulphur hunger of alfalfa was so great, the applications of sulphur increased yields from 50 to 500 per cent. Sulphur deficiency may be indicated by light green color in young leaves with lighter veins showing and also by slow and stunted growth.

#### Minor Plant Foods

The minor plant food elements, iron, manganese, copper, zinc, and boron are usually required by plants in such small quantities that their addition to fertilizers is justified only when based on the results of actual field tests.

#### How Plant Food Is Lost from the Soil

Cropping, leaching, and erosion are responsible for large annual plant food losses from our soils. The crops produced on the farm take up large quantities of the mineral elements and nitrogen that are lost to the fields when they are sold off the farm or wasted in careless handling of manure. Cultivation and lack of sufficient ground coverage have often caused serious leaching and erosion problems. These factors

have made it necessary to supplement plant food in the soil with commercial fertilizers.

Fertilizers are bought and used because of the plant foods they contain. They are used to supplement the natural plant food supplies of the soil and those obtained from farm manure and crop residues. The main purpose for using fertilizers is to realize a profit from the increase in yield of crops from the land on which it is used.

Some of the factors to consider in making fertilizer recommendations are the soil, type, the crop, the rotation, climatic conditions, the manure and crop residues returned to the soil, value of the crops that are to be grown, fertilizer costs, and the funds available for the purchase of fertilizers.

UNIT IX

SOIL ACIDITY AND ITS CONTROL BY LIMING

- I. Soil acidity defined
- II. The cause of soil acidity
  - A. Leaching
  - B. Removal of calcium by plants
  - C. Accumulation of organic or mineral acids
  - D. Accumulation of acid residues of fertilization
- III. Indications of soil acidity
- IV. Tests for soil acidity and methods of correction
- V. Commercial forms of lime and factors in liming
  - A. Fineness of ground lime
  - B. Rate of application
  - C. Time and method of application
  - D. Frequency of application
- VI. Effects of liming
  - A. Correcting soil acidity
  - B. Improvement of the physical condition
  - C. Increase the availability of other minerals in the soil
  - D. Stimulate the decay of organic matter by microorganisms
  - E. Supplying needed calcium to plants and animals
  - F. Increasing the efficiency of manures and fertilizers
  - G. Effects of lime on different crops

## SOIL ACIDITY AND ITS CONTROL BY LIMING

## Soil Acidity Defined

Acidity may be defined as a condition in which the concentration of hydrogen ions is greater than that of hydroxyl ions. When the hydrogen  $H^+$  ions exactly balances that of the hydroxyl  $OH^-$  ions, the concentration is at a point called neutrality. Soils that have certain chemical properties similar to acids are said to be sour or acid soils. This condition is known as soil acidity.

## The Causes of Soil Acidity

Soils become acid when they lose carbonate of lime and other substances of similar chemical nature by leaching. The removal of bases in drainage water is no doubt the most potent cause of soil acidity. Considerable loss of lime occurs in the form of carbonates when the soil is uncropped. Decomposition of organic matter of the soil always results in the formation of carbon dioxide and the development of carbonic acid which tends to cause domination of the  $H^+$  ions in the surface soil, consequently, the removal of bases begins there. Plants remove more bases than acids from soils in the process of their growth. When the above ground portion of the plant is removed from the soil, the bases it contains are removed with it. The manure of growing animals returns only a small portion of the calcium as the calcium in the vegetation consumed by the animal is used in building bone and tissue.

In soils deficient in lime the addition of green manure crops has been considered to temporarily produce an acid condition due to the formation and liberation of organic acids that unite with the basic material to make it neutral.

The continued use of ammonium sulfate on land may result in producing a sour condition. The absorption and nitrification of the ammonia of the salt, and its final utilization by plants, leaves sulfuric acid, which combined with calcium and escapes with drainage water.

#### Indications of Soil Acidity

The failure of such crops as alfalfa, red and sweet clover, which are "sensitive" to acidity may be considered an indication of the need of lime, if other conditions are right. The appearance on the land of acid tolerant species of weeds and grass are an indication of soil acidity. Certain weeds, such as sheep sorrel, wild daisies, poverty grass, paintbrush, buckhorn, and broom sedge are indicators of soil acidity. Also, when red top does better than timothy and bent grasses or poverty grasses replace Kentucky bluegrass and white clover in permanent pastures, one may expect the soil to be deficient in lime. The best way to be certain that the soil is acid and to determine the amount of lime needed, is to test the soil for acidity.

#### Tests for Soil Acidity and Methods of Correction

The usual tests for acidity involve chemical and color changes. The litmus paper test is sometimes used, but this has limited value

since it does not measure the degree of acidity. A strip of blue litmus paper is brought in contact with moist soil; if the paper turns red the soil is acid. If the soil turns red litmus paper to blue, it is neutral or alkaline. Colorimetric tests are now in use, in which soil solutions are treated with chemical indicators and the resultant colors checked against color charts, showing with great accuracy the degree of acidity or alkalinity of the soil.

The hydrogen ion method of measuring acidity uses a scale whereby the intensity of acidity or alkalinity is expressed in pH. A neutral soil is represented by a pH of 7 and the smaller the figure below 7, the greater the acidity. The greater the figure above 7, the greater the alkalinity. The pH unit varies with the degree of acidity; for example, a soil with a reaction of pH 4 is 10 times as acid as one with a pH of 5 and 100 times as acid as one with a reaction of pH 6.

There are certain characteristics that influence the effectiveness of lime in changing the pH action. More lime is required to produce a given change in a clay soil than in a sandy soil. Also, a soil well supplied with organic matter or one that is poorly drained requires more lime to produce a given reaction.

Approximately the following amounts of ground limestone are required to change the reaction one pH in soils containing medium amounts of organic matter: Three-fourths of a ton of ground limestone is needed on sandy soils, one ton on loams and two tons on clays to raise the pH one point on the scale.

## Commercial Forms of Lime

Many materials are suitable for liming soils, the most commonly used commercial forms of lime being ground limestone, burned lime, hydrated lime, ground shells, and marl. They all function similarly and when applied in proper amounts to acid soils, will benefit the growth of crops, especially the legumes, although they vary to a certain extent in effectiveness in acid correcting value. The form to use depends largely on price. Consideration should be given to other points, such as availability, facilities for handling and fineness.

Limestone is the source of almost all of the agricultural lime. Ground limestone in the strictest sense is calcium carbonate. When the rock contains both calcium and magnesium carbonates, it is called magnesium limestone or dolomitic limestone, although the magnesium usually is only a small per cent of the total. Magnesium limestone in general is equally as good as pure limestone for liming. Limestone is prepared for use on the soil by crushing and pulverizing. Ground limestone is the most agreeable form to handle because it is not caustic while both burned and hydrated lime are caustic and will burn the skin, especially in warm weather.

Marl is the term applied to soft, chalky, calcium carbonate that may be found deposited in swampy areas. Although the material is similar in composition and of no greater agricultural value than ground limestone, it generally sells at a higher price due to the

cost of digging and drying. Oyster shells are another source of the carbonate form of lime, being 90 to 95 per cent calcium carbonate. Their use is usually restricted to local areas.

One hundred pounds of pure calcium carbonate when burned will give off 44 pounds of carbon dioxide and produce 56 pounds of calcium oxide. The 56 pounds of pure burned lime are equal to the original 100 pounds of limestone in neutralizing soil acidity.

Hydrated lime is made by adding water to the burned lime. When 56 pounds of burned lime unite with 18 pounds of water to form 74 pounds of calcium hydroxide, it has the acidity correcting value of 100 pounds of limestone.

In order to purchase lime to the best advantage, one must be able to determine which of several forms is the cheapest. It is important to consider calcium or calcium and magnesium content, the purity, and the cost of hauling to the farm and applying to the land in order to determine which form is cheapest to use.

Concentrated forms of lime, such as burnt and hydrated, are more costly to buy but are less costly to haul and spread per unit of available oxide and less quantity is needed per acre. Ground limestone has a cheaper initial cost but is more costly to haul and spread for more is needed per acre.

Fineness of grinding and the composition both determine the effectiveness of ground limestone. The finer the limestone is ground, the more it will cost and the more soluble and immediately effective

it will be in the soil. Limestone passing through a 50 or 60 mesh screen will largely become effective the first year. The coarser particles that will pass through a 10 mesh screen but will not go through a 60 mesh screen are slower in action but more lasting in their effect on the soil. Either the 10 or 20 mesh stone will give satisfactory results. Agricultural workers recommend that at least 90 per cent of the product should pass a 20-mesh and 50 per cent pass a 100-mesh screen.

The rate of application of lime will depend upon both the crop and the soil. Crops requiring large quantities of lime planted on very acid soils should receive more lime than less exacting crops on soils with a low lime requirement. Lime may be applied in sufficient amounts to meet the lime requirements of the soil as determined by chemical test. For legumes such as alfalfa and sweet clover, best results are secured when lime is used in sufficient quantities to approximately neutralize the acidity in the plowed soil. After the lime requirement has been sufficiently met, one should apply a ton of ground limestone or an equivalent amount of burned or hydrated lime once every four years, which is usually sufficient. When the application is in excess of two tons of ground limestone or its equivalent per acre, half of it should be applied before plowing and the other half after plowing.

It is most desirable to thoroughly mix the lime with the plowed portion of the soil. This can be accomplished most economically by broadcasting lime on newly plowed land and mixing it with the top soil

by disking and harrowing necessary for seed bed preparation. In recent years many farmers have followed the practice of hauling lime when convenient and during times when not rushed by other work. Spreading lime on sod before plowing requires less power to pull the spreader and trucks with distributors attached save time by spreading lime on sod, thereby, reducing cost. Lime put in rotation just before the crop most responsive to lime is desired, provided the time is convenient and labor can be used advantageously at that time. The most satisfactory method of applying lime is with the use of a lime distributor.

Various types of lime spreaders are on the market that will do an efficient job of spreading lime. Trucks hauling lime to the farm that are equipped to spread the lime as it is hauled are very popular for each load is spread as it is hauled, saves handling, and the lime does not have time to get hard before it is spread.

#### Effects of Liming

Liming may improve acid soils in several ways; however, correcting soil acidity is probably the most frequently thought of effect produced by liming, yet other effects may be equally as important. Soil derived from silicate rocks usually contain compounds of an acid nature. Decay of organic matter in the soil is another source of acidity. Liming has the power to correct the acidity and certain poisonous substances are neutralized, thus creating an environment

much more favorable to the growth and activity of the helpful soil bacteria, and the growth of tender roots. Limestone enters into a reaction with the acid whereby carbonic acid gas is liberated and a neutral compound is formed. Burned lime forms a neutral compound by combining directly with the soil.

The physical condition of clay soils is known to be affected unfavorably for plant growth by an acid condition, as the fine soil particles become associated so closely that free access of air and water is prevented. When the fine particles gather in small groups, each group behaving as a large particle, the soil particles are then said to have flocculated and the soil has a highly desirable granular or crumb structure. Liming favors flocculation of heavy soils, so that better aeration and drainage that result from the liming of heavy compacted soils are among the important effects of liming. In sandy soils the presence of lime carbonate probably improves the physical condition by acting as a binding agent.

Commercial fertilizers will seldom produce their greatest benefit on extremely acid soil. The availability of all of the essential elements obtained by plants from the soil is affected in one way or another by the reaction of the soil. An acid soil locks up much of the valuable phosphorus, and probably potash. With increasing acidity, calcium and magnesium become less available to plants because of a decreasing supply and some is taken up in chemical reaction with the acids. Iron, copper, zinc, manganese and possibly boron are

less available if the reaction is alkaline or the pH rises above the neutral point. This lowering in availability of certain elements may explain why unfavorable results are sometimes reported when land low in organic matter is limed.

The activity of many soil microorganisms is greatly retarded by acid reaction, and this in turn affects the availability of the nitrogen and other elements whose liberation is dependent on the decomposition of organic matter produced by microorganisms.

Decay of organic matter is accompanied by the production of acids; unless there is sufficient lime in the soil to neutralize these acids, decomposition is slowed down or stopped. The root nodule bacteria of alfalfa and sweet clover are not very active in a soil when its pH value is below 6.5. Liming makes conditions more favorable for their growth.

Calcium is regarded as an important plant food element for building up plant tissues, and crops may be benefited by the direct supplying of needed calcium to the plant, where there are insufficient amounts in the soil.

Alfalfa and sweet clover fail on an ordinary acid soil because they cannot secure sufficient calcium to meet their needs. These crops which respond so well to lime need relatively large amounts of calcium as a nutrient.

Lime is necessary in the formation of bones, teeth, cell walls, as well as in the production of blood and the milk. Egg shells are almost pure lime. Pasture grasses and forage crops, and to less extent

grain largely furnish the needed lime to furnish bones and other tissues without which healthy stock is impossible. Milk contains a goodly quantity of calcium and is one of the most important sources of this element in human nutrition.

It is a good practice to lime an acid soil if for no other reason than to enable the soil to give greater returns from fertilizer and manure. Plant food elements are more available in non-acid than in acid soils, especially phosphorus. The maximum benefits from green manure crops may be secured when lime is applied to an acid soil just before planting the green manure crop, or in some cases, just after the crop is turned under.

Liming is most profitable in growing alfalfa. Alfalfa, sweet clover and red clover are practically a failure on acid soils. When favorable lime and other conditions are maintained, alfalfa and clover grow thick and strong, and weeds are smothered so that they afford little competition. Other crops that are directly benefited by liming when grown on acid soils are: crimson clover, cowpeas, hairy vetch, garden beets, celery and many others.

The following crops tolerate acidity, growing well on slightly or medium acid soil: corn, wheat, oats, timothy, orchard grass and lespedeza.

Raspberries, strawberries, blueberries, and cranberries require high acidity.

Although many crops can tolerate soil acidity they are usually benefited by liming and respond to the application of lime.

In practical farming the rotation rather than the individual crops must be considered. Where corn and wheat are concerned, for the most profitable production, the crops must be grown in a rotation with a legume, usually clover. Legumes are in greater need of lime and invariably grow better in soils that are well supplied with it. Legumes add organic matter and nitrogen to the soil when the soil is limed. Soils that have received the treatments that will insure success with clover are usually well adapted for most field crops.

UNIT X

GREEN MANURING

- I. Reasons for using green manure crops
  - A. Maintain humus
  - B. Improve physical condition of the soil
  - C. Add to the plant food elements
  - D. Furnish food for bacteria which make the vegetable matter available for higher plants
  - E. Conserve soluble plant nutrients that might be lost
  - F. Bring nutrients upward from the subsoil by long-rooted plants
- II. Desirable characteristics of green manure crops
  - A. Rapid growth
  - B. Abundant and succulent tops
  - C. The ability to grow well on poor soils
- III. Three groups of green manure crops
- IV. Factors influencing the crop to use for green manure
  - A. Legumes as green manure crops
  - B. Ability to produce abundance of organic matter under conditions in which it is to be grown
  - C. Time of seeding
  - D. Value of crop that is to follow
  - E. Adaptation
  - F. One-, two-, and three-year rotations
- V. Practical utilization of green manure

## GREEN MANURING

Green manuring means turning under any crop, green or ripe, for the purpose of enrichment of the soil. The practice of green manuring is one of the oldest methods used to maintain or increase the fertility of the soil. The Greeks used this method of soil improvement 300 years before the Christian era.

## Reasons for Using Green Manure Crops

Decaying of green manures forms humus which aids both the texture and moisture holding capacity of the soil. Organic matter serves to bind together a sandy soil and increase its ability to hold water, while organic matter in clay serves as a sponge, thereby aiding in the absorption of water in the soil. It has been shown that while 100 pounds of sand can hold only 25 pounds of water and 100 pounds of clay 50 pounds, the same weight of humus or decaying matter will hold 190 pounds of water.

Aeration, drainage, and granulation are promoted by the organic matter of green manure. Aeration is the circulation of air through the surface soil and subsoil. Air in the soil is necessary for the development of helpful soil bacteria, root growth, and to enable chemical changes to take place. When heavy soil dries, it becomes hard and the roots of the plant suffer from lack of moisture and air. Green manure crops open up the soil promoting a crumb structure in clay, making it porous and improving the tilth. Green manure plowed

under adds the essential elements, carbon, hydrogen, oxygen, and nitrogen to the soil. Dead vegetable matter furnishes food for bacteria which breaks it down and makes it available for higher plants. Green manure conserves plant nutrients that might otherwise be lost by leaching if the land were left bare. This is especially true as to nitrates which may be leached out.

Long rooted green manure crops carry nutrients upward from the subsoil and when the crop is plowed under, this material is deposited within the root zone for the crops that follow.

#### Desirable Characteristics of Green Manure Crops

Crops that grow rapidly and usually those that are capable of good growth during the cool part of the growing season are more useful than other crops for green manuring, since the regular crop has been harvested off the land at that time. Crimson clover, vetch, rye, and rye grass are good examples of such crops.

It is desirable to have abundant and succulent tops for green manure crops because they have moisture content which aid in rapid decay and can be utilized by the next crop more quickly than other type crops.

The ability to grow well on poor land is very important because of the urgent need of organic matter. Crops that will grow well under a wide variety of conditions and are not exacting in soil nutrient requirements are the most useful over wide areas as green manure crops.

Green manure crops may be divided into three groups:

1. <u>Summer legumes</u>	2. <u>Winter legumes</u>	3. <u>Non legumes</u>
Red clover	Crimson clover	Rye
Sweet clover	Hairy vetch	Wheat
Cowpeas	Austrian winter peas	Winter oats
Soybeans	Bur clover	Barley
Lespedeza		Rye grass

#### Factors Influencing the Crop to Use for Green Manure

It is desirable to use a legume when possible as legumes may improve the soil in two ways: by adding organic matter and by increasing the nitrogen content, whereas non legumes add only organic matter. Legumes that are well noduleed get approximately two-thirds of their nitrogen from the air and one-third from the soil. If these crops are turned under, the soil will be richer in nitrogen, by approximately 40 pounds for every ton of hay, as the fertilizing elements taken from the soil are returned, and in addition two-thirds of the nitrogen from the air assembled by the nitrogen fixing bacteria is put in the soil as well as the quantity of organic matter. In studying the clover plant, it has been found that practically two-thirds of the nitrogen contained in it (roots and all) is in the hay and one-third in the roots. Thus, when the crop is taken off the soil, there is left in the roots practically the same amount of nitrogen as was taken from the soil supply and the field is not enriched. Normally the cost of legume seed is higher than non legumes due to the scarcity of seed.

Rye or rye grass have the ability to produce an abundance of organic matter under a wide variety of soil and climatic conditions, they being more tolerant to acidity, poor land, and cold than are legumes.

For the winter cover crop that is to be turned as green manure in the spring, crimson clover is usually preferred (except for bright tobacco), then rye grass or rye is desired. Crimson clover should be seeded not later than two weeks before frost. If a legume is desired after that date, hairy vetch may be used up to two weeks after the frost date. However, it does not offer much control against erosion in the winter and plowing in the spring may be delayed in order for it to get sufficient growth. If the green manure crop cannot be seeded until too late for vetch, rye may be used.

Green manure crops are most profitable when they are followed by cultivated crops of high cash value. In orchards, summer green manuring crops are profitable as they do not sacrifice the main crop.

In the eastern part of Virginia, crimson clover is well adapted because of suitable climate and there is usually sufficient time after the crop is harvested to seed crimson clover. In the tobacco sections, rye grass or rye is used to add organic matter.

When using one-year rotation, green manuring should be with or after a grain crop or after cash crops have been harvested. For example, in a bright tobacco one-year rotation, a non-legume such as rye or Italian rye grass is recommended to keep up organic matter.

Rye planted in the fall provides good cover during the winter and serves as green manure crop in the spring.

The following is suggested for a two-year rotation: First year, corn with soybeans at last cultivation disked for small grain. Second year, small grain and lespedeza, then the lespedeza turned for corn.

The following is suggested for a three-year rotation: First year, peanuts; second year, corn and soybeans with crimson clover seeded at last cultivation; and third year, soybeans followed by rye to be plowed under in the spring.

#### Practical Utilization of Green Manures

Green manure crops may be used in between cash crops of a single season or over a period of years. When the cash crop is a vegetable, which requires high temperatures, both ends of the season may be used for green manure production. Crimson clover and rye or rye grass may be used advantageously. It is usually best to turn under green crops when they have an abundance of tops, approximately at the half mature stage. Green manure crops when turned under decay rapidly, in approximately two weeks, under favorable soil and temperature conditions.

All the grains used for green manure should be turned under by the time they head out or before. Caution must be used in turning rye after it is headed for it has removed much of the soil moisture, it is stiff, and holds the soil loose so that it dries out, and does not decay quickly. In the process of decay of large quantities of

green plants, there may be an enormous increase of the number of bacteria which may consume the nitrates as fast as they are produced, and even decrease the available nitrogen of the soil. Rye should be turned under approximately thirty days before the next crop is to be planted and at such time when there is sufficient moisture available.

Summer green manuring is seldom justified except for poor soils or on sandy soils to improve the physical texture, since summer manuring usually means the sacrifice of a cash crop.

When a three or four year rotation that includes a legume is used, the residue stubble and barnyard manure is usually sufficient organic matter and is more economical than green manure.

UNIT XI

FARM MANURES

- I. Value of manure
- II. Factors influencing the amount and composition of manure
  - A. Quantity and kind of feed consumed
  - B. Quantity and kind of bedding
    - 1. Characteristics of a good bedding
  - C. Kind and age of animal
  - D. Amount of manure produced by different animals
  - E. Loss of manure from exposure
- III. The conservation of farm manure
  - A. Practices to be observed in saving plant food in manure
    - 1. Save the liquid
    - 2. Do not expose manure in piles
    - 3. Haul and spread manure while fresh
    - 4. Store manure properly
- IV. The plant food value of manure
  - A. Supplementing manure
- V. The economic use of manure
  - A. Value of manure to different crops
    - 1. Time of application
    - 2. Rates of application

## FARM MANURES

The student of soil management will find the production, conservation, and utilization of farm manure one of the most neglected and wasteful practices of present day farming. Only a small part of the potential crop production and soil conservation value of manure is actually realized, due to failure to save the valuable liquid portion, and to losses through leaching by improper storage and handling.

## Value of Manure

Farm manure is a mixture of animal excrements and bedding which accumulates in the stables. Manure is of value in soil improvement because of its content of fertilizer elements, organic matter, and the organisms added. The value of manure as a fertilizer is about \$2.50 a ton. These figures vary with different soils and with the current prices of crops and fertilizers. It is said that manure is worth whatever it produces in larger yields of crops.

The principal benefits of manure are indirect. By supplying organic matter it improves the physical character of the soil as well as the water holding capacity, aeration, and temperature relations. It has a favorable effect on the biological activities of lower organisms that function in the soil to make available plant nutrients. Manure applied as a top dressing affords protection from beating rains and reduces erosion. The reducing action of manure decomposing in the

soil aids in making available iron and manganese. It is believed to have a favorable effect in keeping iron and phosphate in solution.

Manure is an effective fertilizer because it contains quick, medium, and more slowly available plant food. The beneficial effects of manure on heavy soils may be of long duration.

The greatest benefits from manure can only be realized when it is used wisely in connection with other good soil management practices, such as lime when needed, reinforcing with fertilizer, proper crop rotation, good drainage, high quality seed, and good tillage.

#### Factors Influencing the Amount and Composition of Manure

The kind of feed is perhaps the greatest single factor in influencing the richness of manure. When animals are fed a large proportion of concentrated mill feeds and grains, the manure produced is rich in plant food. However, these feeds are highly digestible and a smaller percent is recovered in manure. Coarse roughage, such as overripe timothy is low in digestibility and nearly two-thirds of it reappears as excrement and the manure is low in plant food.

Bedding is necessary to conserve values in the manure and to protect the animal from filth. The amount of organic matter and plant food nutrients varies widely in different bedding material. Many different materials are used for bedding such as wheat straw, rye straw, spoiled or refused hay, leaves, and sawdust.

A good bedding has the following characteristics:

1. Should be easily obtainable and cheap.
2. Should keep the stock clean and comfortable.
3. Should have absorptive power for liquids and prevent loss of urine.
4. Should furnish bulk without coarseness.
5. Desirable to have available plant food in the litter for it adds to the value of manure.

Cereal straws are most used because they are usually available on most livestock-grain farms, are relatively cheap, and contain available plant food. Sawdust and shavings are poor in available plant food and add little or no value to manure. Stover, unless chopped or shredded, is best used in feed lots. Alternate layers of straw scattered over the stalks in the feed lots, increase the absorptive power of liquids and cattle trampling reduces coarseness and furthers decay of the material.

The wide variation in the composition of manure from different animals is due principally to difference in moisture content and also to the extent to which they retain plant nutrients from feeds consumed. Moisture content of fresh manure varies widely. Hen manure is about 55 per cent moisture while hog manure is about 85 per cent. Horse, sheep, and hen manures are low in moisture, decay quickly, and are called hot manures, while hog and cow manures are high in water, decay slowly, are are called cold manures. Hot manures heat much more rapidly in storage and give off ammonia.

Type of work and the age of the animal influence the amount of plant nutrients recovered in manure. Manure from grass-fed animals, growing stock, and dairy cows in production is not as rich as that from animals being fattened or work stock fed heavily on concentrates. A young growing animal or a dairy cow producing milk will use considerably more of the nitrogen, phosphoric acid, calcium, and potash of their food for flesh, bone, and milk than is retained by mature animals. The amount of plant food utilized by animals varies, but on the average they use one-fourth of the nitrogen, one-fifth of the phosphorus, and one-tenth of the potassium contained in the food, the remainder being excreted. The table below, which was taken from Maryland Agricultural

Average Yield and Composition of Fresh Excrement from Farm Animals\*

Animal	Composition				
	Excreted per year pounds	<u>Solid excrement</u>			
		Water per cent	Nitrogen per cent	Phosphoric acid per cent	Potash soda per cent
Cows	2,000	84	0.30	0.25	0.10
Horses	1,200	76	0.50	0.35	0.30
Pigs	1,800	80	0.60	0.45	0.50
Sheep	760	58	0.75	0.60	0.30
Hens	35	48.6	1.38	0.50	0.41
		<u>Liquid excrement</u>			
Cows	8,000	92	0.30	Trace	1.4
Horses	3,000	89	1.20	Trace	1.5
Pigs	1,200	97.5	.30	0.12	0.2
Sheep	380	86.5	1.40	0.05	2.0

\*Md. Agr. Expt. Sta. Bul. 122.

Experiment Station Bulletin 122, shows the approximate amount of manure produced by some of our domestic animals and the relative value of each from a nitrogen, phosphorus, and potash standpoint.

Plant food is rapidly lost from manure when it is exposed to the weather. Fermentation and leaching are the processes which bring about this loss. Bacteria decompose the manure and the ammonia gas or nitrogen that is formed is lost to the air. When manure is exposed to weather, the rain causes leaching of soluble material. Experiments have been conducted to determine the rate of loss in exposed manure.

The table below gives the results of an experiment conducted at the Cornell Experiment Station in which both cow and horse manure were exposed over a period of five months beginning late in April.

Loss from Manure Exposed for a Period of Five Months at Cornell Station, New York

	Number of pounds at beginning of experiment		Number of pounds at end of experiment		Percentage of loss	
	Horse	Cow	Horse	Cow	Horse	Cow
Gross weight	4000.0	10,000	1730.00	5125	57	49
Nitrogen	19.6	47	7.79	28	60	41
Phosphoric acid	14.8	32	7.79	26	47	19
Potash	36.0	48	8.65	44	76	8

Cornell Exp. Sta., New York. Bul. 27

## Conservation of Farm Manure

The three principal losses of plant food from manure are due to the direct loss of the liquid manure, leaching, and decomposition. To get the full fertilizing value of manure, the liquid manure must be saved and leaching and loss of nitrogen from fermentation or heating reduced to a minimum. There are several important factors to be observed in saving plant food in manure.

Save the liquid. Of the total plant food in manure, about one-half of the nitrogen and sixty per cent of the potash are found in the liquid portion. This solution is readily available for immediate use by plants. Provide a tight floor and sufficient amount of bedding to absorb the liquid.

Do not expose the manure in piles. Manure should not be piled under the eaves of the barn as there will be losses by both leaching and decomposition. Large amounts of the fertilizing elements are lost by leaching when exposed to the weather. As much as one-half of the plant food content of manure may be lost during five or six months of summer exposure. Decomposition in manure is set up by bacteria, which break down the organic matter and liberate nitrogen that is lost in the form of ammonia gas or is leached out. This is a beneficial process when it takes place after the manure is spread for the nutrients are carried down into the soil for the use of plants. Heavy rainfall and high temperature hasten the loss from manure in an exposed pile. It

is wasteful to distribute manure over the field in small piles to be spread after several months exposure, for there is an excessive accumulation of plant food in spots.

Haul out and spread manure while fresh. Probably the best method to prevent excessive loss from manure is to haul it to the field and spread it as rapidly as it is made or is practical to get on the land.

Store manure properly. It is not always expedient or possible to haul manure to the field and spread daily. When manure has to be stored, three vital points should be met; namely, avoid loss of seepage water from the manure pile; control aerobic decay or fermentation of the manure by excluding oxygen; and keep the manure moist.

Providing covered sheds with tight bottoms affords protection from rain and snow and avoids loss by leaching, due to water seeping through the pile. Keeping the manure compact and moist prevents fermentation and conserves plant nutrients.

A good practice is to let animals run loose in the manure shed. The trampling of the animals keeps the manure compact, and the urine furnishes moisture which aids in retarding bacteria action. The moisture also reduces loss of nitrogen by absorbing gaseous nitrogen.

A tight-bottomed manure pit is the best method for storing manure where it must be exposed to the weather. Both the liquid and solid portions of the manure may be saved. The manure should be well packed and kept sufficiently moist to prevent heating.

## The Plant Food Value of Manure

Manure is not a balanced fertilizer, being deficient in phosphates. Unexposed mixed farm manures contain on the average about 10 pounds of nitrogen, 5 pounds of phosphoric acid, and 10 pounds of potash to the ton.

About one-half of the nitrogen and sixty per cent of the potassium, and from a trace to one-fourth of the phosphorus are found in the liquid excrement. Results have shown manure alone cannot maintain fertility. Repeated heavy applications of manure alone causes lodging of small grain due to so much nitrogen.

It pays to reinforce manure. Phosphates are necessary to supplement manure for best results. The addition of 2 pounds of superphosphate applied to the manure per cow daily is a good practice. Equally good results can be obtained by applying 40 to 60 pounds of 20 per cent superphosphate scattered on each spreader load of manure. Eight tons of reinforced manure per acre applied in rotation may be expected to give good yields.

## \*Crop Increases from Phosphorus in Addition to Farm Manure

8 tons manure per acre	Crop yield, increase per acre		
	Corn Bushels	Wheat Bushels	Clover Pounds
Stall manure only	23.9	10.0	1,281
Stall manure plus 320 pounds of 14 per cent superphosphate	34.3	15.1	2,193
Gain for superphosphate over manure	10.4	5.1	915

\*Thorne, C. E., and Staff. The Maintenance of Soil Fertility. Ohio Agricultural Experiment Station, Bul. 381, pp. 326. 1924.

### The Economic Use of Manure

Although all common field crops respond to applications of manure, it seems to give greater returns when applied to certain crops in rotation. Manure being high in nitrogen is especially helpful to crops producing mainly vegetable growth such as the grasses and leafy vegetables.

Heavy applications of manure reinforced with phosphate are especially profitable for vegetables. Fresh manure is not recommended for potatoes as it has a tendency to increase scabbiness. For potatoes best results are secured by applying the manure to the preceding crop or applying it in the fall and turning it under.

Corn, being a heavy user of nitrogen, responds best of all the grain crops to applications of manure. Coarse manure is best applied to land and plowed under before corn.

Another good place for manure is on grass sod that is to be cut for hay the following summer. These applications may be made during winter when other crop land is too wet to haul over.

Lodging may result when manure is applied to small grain that is well supplied with nitrogen. However, an application on thin spots is profitable. Usually it is preferable to put the manure on corn in rotation rather than on small grain.

A manure spreader is said to be one of the most profitable pieces of equipment on a livestock-grain farm. It breaks up and applies the manure evenly, and does the job more quickly and easily.

Light applications at frequent intervals are the most profitable. Eight tons applied once in a four-year rotation gives larger returns for the manure than 16 tons applied every 8 years.

Plowing under of manure is usually preferable especially on heavy soil, because it has a loosening effect. On light soil it may be applied to the surface and disked under with good effects.

UNIT XII

SPECIAL SOIL EROSION CONTROL PRACTICES

- I. Maintenance of soil fertility
- II. Contour strip cropping
- III. Terracing
- IV. Rotation of crops for saving soil
- V. Control of terrance outlets with grasses
- VI. Continuous use of close-growing cover
- VII. Green manure and cover crops
- VIII. Converting severely eroded cultivated land to permanent grasses  
or trees
- IX. Border strips and wild life plantings
- X. Pasture management for erosion control
- XI. Contour furrows in pastures
- XII. Gully control

## SPECIAL SOIL EROSION CONTROL PRACTICES

Soil erosion began when man first began to cultivate the soil. Through the ages, soil erosion has exerted a tremendous force on the course of civilization. In the early development of this country the settlers tilled the soil until it had lost a great amount of the plant nutrients. As the soil became depleted and productivity was reduced, the land was abandoned and more fertile land was found where the same procedure of wasteful destruction was again practiced until no more new free land was to be found.

Water erosion is influenced by such factors as slope, soil type, land use, and intensity of rainfall. The rate of erosion has been greatly speeded up by poor cultivation practices, one crop systems of farming, over grazing, and sometimes burning.

The Soil Conservation Service established by Congress in 1933 has been one of the greatest agencies for conserving the soil of our country. The practices for controlling soil erosion treated in this unit were developed by the above agency. Credit should also be given to the AAA program for its part in providing payments for fertilizer and lime to help farmers maintain the fertility of the soil.

## Maintenance of Soil Fertility

Probably the most potent cause of soil erosion is simply depleted fertility due largely to improper management of the soil. The first step in the control of erosion is the maintenance of reasonably high

productivity. In most soils in Virginia low crop production is due more to the lack of phosphorus than to the lack of any other single plant food element. Potassium is usually deficient in sandy soils. By the addition of these two elements and lime, where it is needed, usually thrifty crops may be grown that produce an abundance of leaves, stems, and roots that protect the soil against erosion. The stubble of small grain and hay after harvest checks the movement of water over the soil and the masses of roots aid greatly in binding the soil particles together.

#### Contour Strip Cropping

Contour strip cropping is the production of the regular field crops in long, narrow strips of variable width, on which close-growing vegetation crops alternate with clean-tilled crops, placed crosswise of the line of slope, approximately on the contour. The effectiveness of strip cropping depends on the production of close growing, erosion resistant crops in alternate strips of cultivated crops. Contour strip cropping has the following advantages: divides the length of slope, checks the speed of run-off water, filters out the soil being carried off, and increases the retention of rain water by the soil. The close-growing crops generally used in a strip cropping plan between strips of row crops, are the small grains, legumes and grasses. All operations of tillage, seeding, cultivation, and harvesting should be done on the contour. Strip cropping, combined with contour tillage, crop rotations, winter cover crops, diversion

ditches, and terraces in gullied fields, have proved practical, economical, and effective in conserving soil and water on cultivated land.

### Terracing

The primary functions of a terrace is the interception of water, which is absorbed, or to permit excess water to flow slowly from the field without attaining erosive speed.

There are two general types of terraces in common use. The absorption type structure is used primarily in fields in which soils readily absorb water, where moisture must be conserved to grow a crop successfully. These terraces are level throughout its length and the ends are practically closed. The graded broad base modified Mangum and micols terraces are used primarily to check the rate of soil loss by providing orderly surface drainage.

### Rotation of Crops for Saving Soil

The rotation of crops has many advantages for reducing soil and water losses as compared with continuous growing of one crop. The close tilled crop exposes the soil to the maximum erosion; the small grain do not allow as much erosion; and the grasses and legumes effectively control erosion provided there is sufficient stands for complete coverage of the soil. The loss of both soil and water from the above rotation is low compared to the loss from the continuous

corn crop. Crop rotation tends to maintain a normal content of organic matter, which may greatly increase the rate of water intake and greatly reduce the amount of run-off. When the rotation plan is based on the proper land use, including contour cultivation, complete or modified strip cropping, the problem of erosion is greatly reduced.

#### Control of Terrace Outlets with Grasses

Close-growing vegetation may be used as an effective control for water after it leaves the terrace ends. Whenever it is possible to do so, terrace water is turned into and spread over a well-sodded pasture field or into woods on a moderate slope. If neither pasture sod nor woods are convenient, a meadow strip in the natural depression, well sodded with grasses suitable for hay, should be used. This meadow strip should be of sufficient width to give ample spread of water.

#### Continuous Use of Close-Growing Cover

Soil completely covered with vegetation offers a desirable condition to absorb water and resist erosion, especially if the soil is well diffused with roots. Close growing crops reduce the direct impact of rain on the surface soil and the dense top growth of plants reduces the speed of water flowing over the soil surface. By decreasing the speed of run-off water the power to pick up and carry soil particles is greatly lessened. The small grains, grasses, and legumes are classed as soil protecting crops, and are particularly desirable for inclusion in the cropping system on sloping soils subject to erosion.

### Green Manure and Cover Crops

Erosion has progressed to a more serious degree in the cotton and tobacco sections than elsewhere in the country due to lack of organic matter in the soil. Erosion goes forward exceedingly rapid into the subsoil, which contains little organic matter. The most practical way to replace organic matter in the soil is by rotation. The next best method is by the use of green manure and cover crops turned under. Green manure or cover crops not only supply organic matter but aid in the control of erosion by improving the physical condition of the soil enabling it to take up and hold larger quantities of water in a way favorable to plant use.

### Converting Cultivated Fields to Pastures or Trees

Beyond doubt large acreages of land now planted to cultivated crops would be more profitable if it were made into pastures where the soil is suitable for pasture purpose. This is especially true on slopes that are losing soil too fast to remain long in cultivation. Where soil is too steep or too badly eroded for cultivated crops or pasture and there is sufficient depth of soil, planting trees is often profitable, affords erosion control, and tends to bring the land back into productivity.

### Border Strips and Wild Life Plantings

Border strips are used in protected places in fields that are

especially subject to erosion, such as, the borders of fields, drainage ditches, terrace outlet channels, and roadside ditches. Often the same crops are grown in the border strips as occupy the field strips. Many of these small areas may be devoted to wild life plantings. *Lespedeza sericea* is a good example of a planting that may be used for both soil erosion control and food for birds.

#### Pasture Management for Erosion Control

The cover of grasses in many of the pastures in Virginia is too sparse to check erosion effectively. Often it is necessary to plow, fertilize and lime and seed these fields with a suitable mixture of grasses and legumes in order to establish a permanent pasture of good quality palatable grasses for livestock. Clipping weeds and small bushes in pastures is often necessary to keep them from shading or crowding out the desirable grasses. Temporary pastures will provide relief for permanent pastures during both summer and winter.

#### Contour Furrows in Pastures

Contour furrows in pastures may help to hold soil, seed, and water in the pasture, thus aiding vegetation in becoming established. Erosion spots and small gullies in pastures should be fertilized and seeded and protected from overgrazing by a covering of stable manure, straw, or brush.

## Gully Control

Gullies are channels formed by run-off water from the soil. The control of run-off water in a narrow channel of a gully is usually difficult and expensive. Often diversion ditches or terraces are used to intercept the water before it enters the gully and carry it to some place more easily protected than the original gully. If prompt action is taken many of the small gullies in Piedmont, Virginia, may be stopped by the use of grass dams, which are made by filling old fertilizer sacks with grass roots and soil or with grass seed and soil. Brush and loose rock are often sufficient for checking gullies. Establishing vegetable covering as quickly as possible is usually the best method of control.

## APPENDICES

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VIRGINIA POLYTECHNIC INSTITUTE  
DEPARTMENT OF VOCATIONAL EDUCATION

Blacksburg, Virginia

May 22, 1946

TO: A Selected Group of Agriculture Teachers

Mr. J. E. Strickler, one of our graduate students, has selected as his thesis problem, SOIL MANAGEMENT INSTRUCTION IN AGRICULTURE CLASSES. We believe that information concerning the practices and opinions of a representative number of teachers will be very valuable in making the study.

If you can fill out the enclosed form and return it to Mr. Strickler, using the enclosed self-addressed envelope, your kindness will be greatly appreciated. We have reduced the questions to a minimum and I believe you can answer them in a very few minutes.

As a result of this study we hope to develop some material that will be of considerable assistance to you in your teaching.

Sincerely yours,

H. W. Sanders, Professor  
Agricultural Education

at

Department of Vocational Education  
Blacksburg, Virginia  
May 23, 1946

Soil Management Instruction In Agriculture Classes:  
A graduate study in Agricultural Education by James E. Strickler

- I. Some of the units in Soil Management are listed in item II below. Do you commonly teach these as separate units? \_\_\_\_\_ Or in connection with some other farm job? \_\_\_\_\_ Or both? \_\_\_\_\_.
- II. Please give the information called for below with reference to the Soil Management units you teach or think should be taught. Add other units in the blank spaces if the suggested list does not cover your needs.

	: Units actually	: Check if you think
	: taught	: unit should be
	: Yr. or Yrs:Periods	: taught and give
	: 1 2 3 4 : (Number)	: year
1. The origin of soils	:	:
2. Physical properties of soils:	:	:
3. Soil organisms	:	:
4. Organic matter in soils	:	:
5. Soil water	:	:
6. Soil tillage	:	:
7. Crop rotation	:	:
8. The plant food elements	:	:
9. Soil acidity	:	:
10. Green manures	:	:
11. Barnyard manures	:	:
12. Special soil erosion control practices	:	:
13.	:	:
14.	:	:
15.	:	:

III. Lesson plans:

1. Do you have adequate lesson plans for teaching soil management jobs? \_\_\_\_\_
2. Number of written plans on file. \_\_\_\_\_
3. Would prepared plans be of help to you? \_\_\_\_\_ If you would like plans indicate the ones you would like most. Use the numbers of the units in Item II. \_\_\_\_\_

IV. Reference materials:

1. Do you have adequate reference material? \_\_\_\_\_
2. List below the references you have found most helpful. Limit your number to three:  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

VI. What do you consider the greatest need in teaching soil management units? Check the one item you consider most important.

1. Providing suitable references \_\_\_\_\_
2. Finding sufficient time in the teaching calendar \_\_\_\_\_
3. Providing suitable lesson plans \_\_\_\_\_
4. Organized technical information on unit basis \_\_\_\_\_
5. Securing pupil interest \_\_\_\_\_
6. \_\_\_\_\_

VI. General information:

1. Length of class period in your school: \_\_\_\_\_ Minutes
2. Years of teaching experience (in Agriculture) you have had. \_\_\_\_\_
3. Name \_\_\_\_\_
4. School \_\_\_\_\_
5. Date \_\_\_\_\_