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Management of Tennessee soils

Lonnie James Strickland

To the Graduate Council:

I am submitting herewith a thesis written by Lonnie James Strickland entitled "Management of Tennessee soils." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Eric Winters, Major Professor

We have read this thesis and recommend its acceptance:

L. N. Skold, J. K. Underwood

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

May 15, 1949

To the Committee on Graduate Study:

I am submitting to you a thesis written by Lonnie James Strickland entitled "Management of Tennessee Soils." I recommend that it be accepted for nine quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Eric Winters
Major Professor

We have read this thesis
and recommend its acceptance

L N Skold

J. K. Underwood

Accepted for the Committee

E. G. Waters
Dean of the Graduate School

MANAGEMENT OF TENNESSEE SOILS

A THESIS

Submitted to
The Committee on Graduate Study
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

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by

Lonnie James Strickland

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CHAPTER I

INTRODUCTION

Soil management involves the use of proven practices which aid in the maintenance and improvement of soil fertility and crop yields. There is a distinction between soil management and farm management. Farm management includes the handling, manipulation and integration of all the farm enterprises. Thus crop management, pasture management, and livestock management as well as soil management are a part of the problems involved in managing a farm. Certain practices such as tillage and fertilization may be considered as both crop management practices and soil management practices.

When Tennessee soils were first cleared for cultivation the pioneers removed the trees, shrubs and other undergrowth. This was nature's use of the land. Man's use, by clearing, interfered with nature's pattern causing the land to be left unprotected from such things as climatic forces and uncontrolled movement of run-off water. Most of the land clearing was for row crops. Under this use the surface soils were quickly depleted of original organic matter and spongy surface soil. After a few years the land was abandoned and left to nature to heal and another tract cleared and cultivated. This process has continued until now there is very little land left for clearing and exploiting. Now the selection of proper land use is one of the foremost problems in soil management.

The quality of management may be excellent, good, fair, or poor depending upon whether the use of the soils is constructive or destructive in nature. In other words, is the operator "mining" the soils, taking all and returning nothing? Does he allow his soils to wash away, losing both soil materials and soil fertility? Does he use the land without regard for its physical use suitability? Such practices may be considered as poor soil management. If instead the soil is regularly fertilized and manured to return fertility; tillage is performed on the contour at the proper degree of moisture; the land is used as nearly as possible according to its physical suitability, and other "good" practices are followed, then the management is good or excellent.

Proper Adjustment of Land Use

Involved with the problem of land use is the adjustment of use to fit the operator's demands for row crops, sod crops, pastures and forests so that a maximum return may be produced over a long period with minimum loss of soil fertility, soil material, labor, and with a minimum capital investment.

Each farm presents a different problem and requires a different solution because of its own individual pattern of soil types, slopes, erosion, and economic characteristics such as size of farm, type of farming, and economic demands of the family. Under the varying economic conditions of each farm it is not always possible to utilize each area of land according to its best adapted use. Then the problem of crop selection and the choice of suitable rotations arises. There is also a further problem of determining which supplemental land use measures are practical to allow the use of previous choices; is it heavier fertilization, terraces, contour tillage, strip cropping?

Determination of land use influences many factors which control to some degree the success of other soil management practices. It is a very simple and comparatively easy task to suggest adjustment in land use over a large area such as a community, county, or state. But, it is not on these large areas that the problem will be solved. It must be on the individual farm, whether it is a small subsistence farm or a large specialty farm. When the problem is solved on each individual farm the results will be effective in the community, the county, and the state.

Despite the many and varied conditions there can be set forth a few standard yet flexible suggestions that may be applied to some degree on all farms. Some of these suggestions are:

1. Select the more fertile, less erosive and nearly level lands for intensive use in row crops.
2. Select crops that are adapted to the physical characteristics of the soil.
3. Use the undulating and rolling lands in carefully planned rotations tailored to fit the individual soil pattern.
4. Use the strongly rolling and hilly lands for sod crops, such as small grains, rotation pastures, perennial hays or permanent pastures.
5. Use the steep lands with deep soils for permanent pastures; the shallow soils for forest.

6. Use stony lands for pastures or forests.

7. Use the wet lands for permanent pastures.

Often it is impractical to use all lands on a farm as suggested above. Then it becomes necessary for other practices to support the compromise use in order to protect and conserve the soils. Under such conditions the following practices are suggested:

1. Where row crops are necessary on undulating to rolling lands use the combination of a carefully planned rotation together with contour tillage, terraces and/or strip cropping.
2. On strongly rolling and hilly lands used for row crops a combination of carefully planned rotations, contour tillage and strip cropping are necessary.

Maintenance of Fertility

The soils of the state vary greatly in their natural fertility. Fertility is removed from the land by leaching, sale of crops, livestock, livestock products and by erosion.

The rate of leaching varies from one soil to another. In one soil type it is quite rapid and in another it is slower. The harmful effect of leaching is the removal of plant nutrients from the soil. The reduction of leaching involves such problems as drainage and maintaining a land cover throughout the seasons.

Soils of very slightly acid to neutral reaction are more favorable for the best growth and productivity of most crops grown in Tennessee. The soil also is in a more favorable condition to receive fertilizers and hold them in an available form for plants. Originally, most soils of Tennessee were medium to strongly acid in reaction. Therefore, liming the soils is necessary to maintain favorable conditions for most crops.

Soil erosion removes soil fertility by washing off soil material, including both organic and mineral matter containing plant nutrients. The control of these losses involves the proper choice and selection of crops, rotations, fertilization, to promote vegetative growth; and engineering methods of erosion control, such as contour tillage, strip cropping and terraces. The problem often is to determine what erosion control methods will serve the purpose most economically and to the best advantage.

The removal and sale of cash crops, livestock and livestock products results indirectly in the removal of soil fertility. The amount removed is determined to a great extent by the type of farming and the amount of manure returned to the fields. Too often losses of fertility by this means are not readily recognized as the drain is gradual over a long period of years.

Maintenance of organic matter is almost synonymous with the maintenance of soil fertility. The high water-holding capacity of organic matter decreases the erosiveness of the soil and increases the water absorptive capacity. The physical condition of the soil is improved by organic matter, making the soil easier to work. The maintenance of a medium organic matter level is a very difficult problem, but is of sufficient importance to receive constant attention.

Insects and diseases indirectly affect the maintenance of fertility and organic matter by reducing vegetative growth or even eliminating the production of certain crops. Examples are the nematode injury and potato scab.

It is impossible to maintain soil fertility with any one cure-all. Instead it requires a combination of practices, all of which are aids but none of which can perform the job alone. Among these aids are liming, commercial fertilizers, green manures, barnyard manures, carefully planned rotations, control of erosion, control of insects and diseases, and prevention of excessive leaching. Some of these methods of fertility maintenance are complementary to each other. As an example, liming increases the efficiency of commercial fertilizers by changing the soil reaction and thus prevents the locking up of certain plant nutrients by other minerals within the soil. It also makes the soil more suitable for legumes which gather nitrogen from the air. Carefully planned rotations aid in controlling erosion, utilizing residual fertilizer material and preventing excessive leaching.

Social and Economic Considerations

Tenantry

Tenantry may be considered as a social problem rather than a soil management problem. However, it creates problems in both fields. The intensity of the problem depends upon the type of tenantry followed, whether cash tenant, share tenant or cropper. Too often the tenant is interested in the land only to the extent of what he can expect to get out of it in one year. The tenant cannot be blamed too much for this attitude as he never knows how long he may be able to continue leasing the same land. Under such conditions of rental he does not feel free to make any investments in capital land improvements. Instead he is interested primarily in a cash crop, usually a soil-depleting instead of a soil-conserving crop. His interest in fertilizers is only for the immediate crop. He is not interested in planting winter cover crops as he does not know that the land may be had for the next year. Often a farm operator using share tenants and croppers is unable to farm to the best interest of the soil because he must allow the tenant a certain acreage of cash crops in order to retain the tenant. The present tenant leasing terms are definitely a problem in obtaining the best soil management on a large number of farms in every county of the state.

The problems presented by tenantry as related to soil management are difficult to solve and will require much time and patience. These problems point out the need for: (1) Education of tenants to values of soil improvement; (2) longer term rental leases granting compensation to the tenant for unused capital soil improvements; and (3) improved living conditions for tenants.

Type and Kind of Farm Machinery

In many communities there is a scarcity of sufficient farm machinery to encourage better practices of soil management. The available machinery to the farm often are the more simple types capable of doing only a small amount of work and not adequate to perform all tasks.

An example of this condition is the farm which owns only horse-drawn plows and a few hand tools. With such equipment a large amount of time is consumed in land preparation, distributing manure and fertilizer, cultivation and harvesting. Such implements discourage the seeding of small grains, winter cover crops and perennial hays. Consequently, the type and kind of farm machinery available materially affects the use of the soils. It often determines whether a good rotation is followed or green manure or barnyard manure properly used. The type and availability of machinery determines the timeliness of performance of certain jobs.

Cooperative ownership of certain implements will aid in improving these conditions. Custom work by owners will help also.

Capital

Available capital is one of the important economic considerations in soil management. Often sufficient capital is not available to make the necessary investments in lime, fertilizers, seeds and machinery. The same problem is involved in terracing, drainage and other capital improvements for the maintenance of the farm. Much effort has been made by the government to aid farmers to borrow capital for many purposes. This has helped materially in assisting farmers in obtaining the needed capital for their many purposes.

Education

A knowledge of the physical characteristics of soils and the ability to interpret these characteristics as they affect the use of the land, its crop adaptability, its erosiveness and its relative fertility will enable the farmer to more nearly make good land use adjustments.

Benefits of Good Soil Management

Benefits derived from good soil management are many and far reaching. Some of the immediate effects are larger crop yields, increased income, lower unit production costs, fewer areas of "worn-out" abandoned land, fewer gullies and less erosion. As a result of these benefits further values such as improved housing, fencing and higher living standards are derived indirectly from good soil management practices.

Lands farmed under good soil management are supplied the necessary minerals for adequate crop growth and development. These minerals are then used by the crops and later by the consumers of these commodities. Such commodities are more nutritious and have higher food or feed value than similar crops grown on lands less well supplied with the necessary minerals. Therefore, good soil management is reflected in the health and strong bodies of the farm animals, the farmers, and the public. Consequently, in some respects good soil management is a responsibility of not only the farmer but of the public as well. It is to the interest of the health and nutrition of the public that their food be grown on lands well cared for and managed.

CHAPTER II

LAND CLASSIFICATION

Attempts have been made by different agencies to group soils into land classes that would fill the need of a broad group of people working with the soil. However, none of the classifications is entirely satisfactory. Probably it is impossible to set up a single classification that will fill the needs of both the land planner who deals with large areas and farm managers who are interested only in the relative small areas involved on the farm.

One difficulty of setting up a classification suitable to all interested is the large number of factors affecting the use of land for any given purpose. These factors and their influence vary greatly with the purpose or objective. Recognizing the above difficulties, no attempt will be made here to furnish any overall classification. Instead the land classes as established by the Division of Soil Survey, Bureau of Plant Industry, Soils and Agricultural Engineering, of the U.S.D.A., will be presented.

Purpose of Land Classification

The purpose of classifying soils into land classes is to separate the soils into groups for particular uses, such as row crops, sod crops, permanent pastures and forestry. To be most useful the classification should include groups of soils that may be used for such purposes with a minimum of management problems. After a broad grouping they may be further divided into smaller groups to fit the suitability of a particular crop or other purpose. An example would be lands particularly suited to tobacco, truck crops, or corn. The growth habits of corn are such that it will grow and produce on lands well suited to tobacco or truck crops, though often due to internal drainage or textural characteristics tobacco or truck crops are not suited to all land suitable for corn. Similarly, land adapted to red clover or alsike clover is not always adapted to alfalfa.

Factors Involved in Classification

Soils that are easily conserved, easily worked and productive, are classed as the best lands for agriculture. As the ease of conservation, ease of working or the productivity of the soil is reduced, the desirability for agricultural use is reduced proportionately. The physical characteristics of the soil determine its suitability for different uses.

The characteristics affecting the adaptability of a soil may be divided into external and internal characteristics. The external factors may be studied and rated with little effort. Observation of the internal characteristics may require digging a hole or boring a hole unless a good ditch bank or road bank is convenient where the soil may be examined layer by layer.

The external characteristics which affect the suitability of the soil for different uses are: (1) the length and steepness of slope; (2) the kind and degree of erosion, whether gullied, sheet eroded or uneroded; (3) the amount, size and distribution of stone or outcropping bedrock; and (4) drainage. These characteristics occur in many combinations with varying degrees of expression. They range from one extreme of level or nearly level, uneroded, free of stone, soil with moderate drainage to the other extreme of the very steep slopes, more or less eroded, quite stony, excessively drained soils; with many gradations between these two extremes.

Internal soil characteristics which affect the adaptability of a soil for different uses are: (1) organic matter or humus content; (2) texture or size of surface and subsoil particles (35); (3) the structure or arrangement of the soil particles in the surface and subsoil; (4) the depth of the soil to bedrock, hardpan, or any layer so dense as to interfere with water movements; and (5) the internal drainage or depth of water table.

These internal characteristics of the soil are closely interrelated or complementary to each other in the way they affect the soil for various uses. Soil color is an indication of the relative content of organic matter and degree of drainage and aeration. This is shown in Tables I and II.

TABLE I

RELATION OF SURFACE SOIL COLOR TO
ORGANIC MATTER, DRAINAGE AND AERATION

Color	Relative Content Organic Matter	Drainage	Aeration	Soil Series Examples*
Black	Very high	Fair	Fair to slow	Burgin, Dunning
Brown	High	Very good	Good	Decatur, Maury, Memphis
Red	Low to medium	Good	Good	Sheet eroded Decatur, Dewey, Baxter, Fullerton, Maury, Memphis
Yellowish	Low	Fair	Fair	Dickson, Pace, Grenada, Dulac
Grey	Very low	Excessive or slow	Excessive or slow	Clarksville, Bodine, Robertsville, Guthrie, Calhoun, Almo

* Soil series of Tennessee which are typical examples of the relationships described in the table.

TABLE II

RELATIONSHIP OF SUBSOIL COLOR TO DRAINAGE AND AERATION

Color	Drainage	Aeration	Soil Series Examples*
Red or Brown	Adequate Good	Adequate Good	Decatur, Dewey, Baxter, Hagerstown, Maury, Memphis, Loring
Yellow	Moderate	Moderate	Sequoia, Needmore, Dickson, Paden, Dulac, Providence, Grenada
Light Yellow	Slow	Slow	Callaway, Taft, Hatchie, Monongahela
Gray	Slow to very slow	Slow to very slow	Robertsville, Guthrie, Tyler, Calhoun,Almo,Carroll

* Soil series of Tennessee which are typical examples of the relationships described in the table.

The relative content of organic matter materially influences the structure of the surface soils of all textures. With increasing organic matter the sandy loams and silt loams become less of a single grain structure and more granular. In the clay loams and silty clays the influence is also more toward a granular structure with structure particles being softer.

Soil texture and soil structure are very closely related. The texture influences materially the structure of a soil. A sand would have only a single grain structure, very open and porous. A sandy loam would also have a single grain structure but less porous than a sand. As the soil particles become increasingly smaller in size the structure becomes more clearly defined and the porosity of the soil is proportionately affected.

Relationship Between Soil Characteristics and Land Use

The relationship between soil characteristics and land use is shown diagrammatically in Fig. No. 1. The soil characteristics are physical and are both internal and external. The degree of expression of any one of these individual characteristics affects the land use accordingly. As an example consider a soil on a steep slope, it may be uneroded with a varying amount of stone, and deep, as would be the case of the Dellrose soils in the outer Central Basin. The strong slope causes the land to be very difficult to work except with the crudest of implements, and difficult to conserve, even though it is fair to high in productivity. Such a soil would not be too well suited to short rotations or frequent row crops, but instead better suited to pasture or forest use that requires little working and offers few problems of conservation. In comparison consider soils such as a nearly level Decatur silt loam, Memphis silt loam, or Maury silt loam that are uneroded. These soils are deep, well drained, of good texture, structure, and medium in organic matter. They are relatively easily conserved and worked, and are quite productive of crops adapted to the area. Such soils consequently are adapted to a relatively intensive use. These same soils may in certain instances be so severely eroded as to prevent their economic use for anything other than pasture or forest, thus placing them in a different land class. The expression of internal characteristics such as drainage, texture, and structure, often determines the adaptability of soils to certain plants. Corn, for instance, is not well suited to the Colbert soils due to the heavy texture, cloddy structure and shallow depth of this series. The crop suffers for lack of moisture due to limited root penetration and poor tilth conditions, resulting in low yields. Alfalfa and early planted crops are not well adapted on soils of imperfect or slow internal drainage. Hence an understanding of the effects of physical characteristics of soils upon plant growth or productivity, workability, and conservability enable the farmer to reduce risks of crop failure.

The six relative terms used to describe workability and conservability are excellent, very good, good, fair, poor, and very poor (36). Soils of excellent workability are generally of light or medium texture, stone free, relatively level and require minimum effort in tillage and harvesting. It is successively more difficult to perform normal farming operations on soils of very good, good, and fair workability, but such

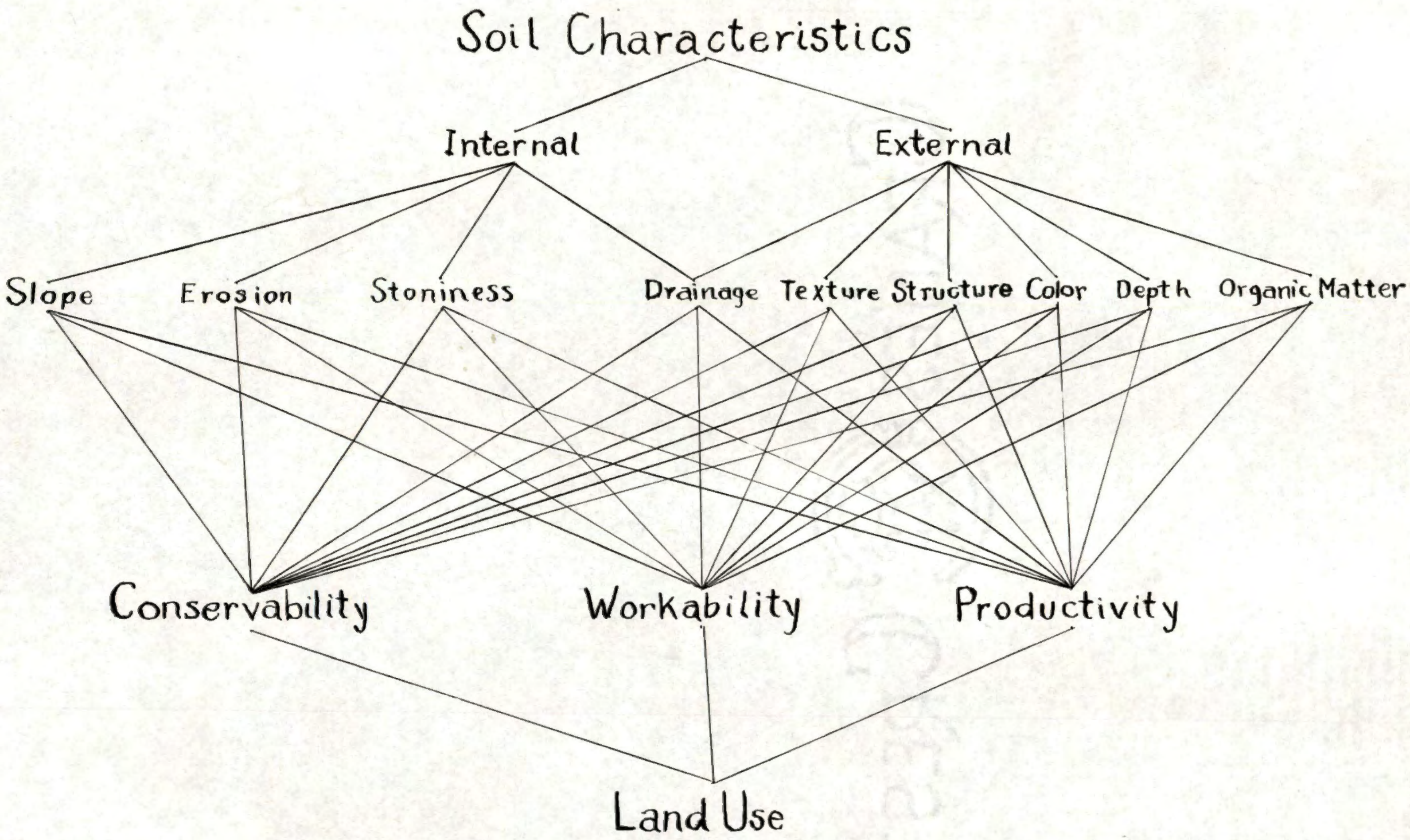

Fig. 1. RELATIONSHIP BETWEEN SOIL CHARACTERISTICS AND LANDUSE

operations are generally feasible for crops that require tillage even on soils of fair workability. Silty clay or clay soils, hilly soils or soils so stony as to interfere seriously with cultivation are considered to have fair workability. Soils on which normal tillage operations can be performed only with great difficulty are considered to have poor workability. The soils of very poor workability are so steep or so stony, or both, that tillage is generally limited to the use of hand implements.

The six terms applied to conservability are also relative. The ease with which the content of available plant nutrients can be maintained at a high level; the ease with which runoff and consequent loss of soil material and water can be controlled; and the ease with which good tilth and good conditions for tillage can be maintained are the principal factors considered. Excellent conservability means that productivity and workability can be maintained with minimum intensity of management. Very good, good, and fair conservability represent soil conditions that require successively more intensive management for maintenance of productivity, workability, or both, but both can generally be maintained under the good management practices that are generally feasible. Poor conservability represents soil conditions that to conserve productivity and workability, or both, require intensive management practices that are generally not feasible on most farms. Very poor conservability represents extreme difficulty in maintenance of productivity or workability, or both.

In separating soils into five physical land classes, the productivity, workability, and conservability of each soil is considered. It is assumed that soils only moderately well suited, both to tilled crops and to pasture, are better suited to agriculture than soils that are poorly suited to crops but well suited to pasture. This assumption is made because soils well suited to crops are limited on more farms than are soils well suited to pasture.

The five classes of soils fall into two groups: In one, the productivity, workability, and conservability are sufficiently good for them to be considered at least fairly well suited physically to crops as well as pasture; in the other, one or more of these three factors is sufficiently extreme to make the soils poorly suited physically to crops that require tillage.

The first group consists of the first three classes, the limits between them being chosen to approximate the concepts of excellent, good, and fair cropland respectively. These three, in decreasing order of physical suitability for agriculture, are the First, Second, and Third class soils.

The second group consists of the two remaining classes. In one, the soils are at least fairly well suited to the production of permanent pasture; in the other, they are poorly suited to permanent pasture and are probably best suited to forest. The first of these two sub-groups comprise the Fourth-class soils; the second, the Fifth-class soils.

The five physical land classes are defined in terms of the relative physical suitability of the soils for agriculture under present conditions. Within that definition, however, the range of relative physical suitability for crops that require tillage, and for permanent pastures, are given.

First Class Soils

The First-class soils are physically very good soils. They are good to excellent for crops that require tillage and also for permanent pasture. Compared with other soils, all are relatively well supplied with plant nutrients, but even on the most fertile soils some crops are responsive to fertilizer amendments. All are well drained and yet their physical properties are such that they retain moisture well. Good tilth is easily obtained and maintained, and the range of moisture conditions suitable for tillage is comparatively wide. The soils are relatively well supplied with organic matter. The physical properties favor normal movement of air and moisture and facilitate root penetration.

None of these soils is characterized by any prominent adverse soil condition. They are almost free of stones; their surface relief is favorable to tillage and other field operations, and none is severely eroded or highly susceptible to erosion. Productivity is high for many crops; and the conservation of soil fertility and of soil material itself is relatively simple under common farming practices. All the soils are well suited physically to most of the exacting and intensively grown crops common to the state. Some of these soil types in the state include:

Abernathy silt loam

Cumberland silt loam

Decatur silt loam

Dewey silt loam

Dexter silt loam

Emory silt loam

Hagerstown silt loam

Huntington silt loam

Lexington silt loam

Lintonia silt loam

Maury silt loam

Memphis silt loam

Pope silt loam

Staser silt loam

Tigrett silt loam

Second Class Soils

The Second-class soils are physically good soils. They are fair to good for crops that require tillage, and fair to excellent for permanent pasture.

They are at least moderately productive of most of the crops commonly grown. Their physical properties are at least moderately favorable for tillage, maintenance of good tilth, normal circulation, and retention of moisture. None has slopes greater than 15 percent; none is sufficiently stony to interfere seriously with field operations, and none is severely eroded. Although each is moderately deficient in one or more characteristics that contribute to productivity, workability, or conservability, none is so seriously deficient as to make it poorly suited physically to use for crops that require tillage.

The deficiencies vary widely among the soils. Some are fertile but sloping and moderately eroded; others are almost level and uneroded but imperfectly drained. The management requirements differ widely because of the many kinds of soils included. All are relatively similar in their suitability for agriculture, although the management practices, by means of which the benefits of their suitability are realized, may be greatly different.

Some of these soil types in the state include:

Briensburg silt loam	Holston silt loam
Collins silt loam	Humphreys silt loam
Dickson silt loam	Lindside silt loam
Egam silt loam	Mercer silt loam
Freeland silt loam	Nolichucky silt loam
Fullerton silt loam	Ooltewah silt loam
Grenada silt loam	Philo silt loam
Greendale silt loam	Providence silt loam
Hamblen silt loam	Richland silt loam
Hartsells silt loam	Sequoia silt loam
	Wolftever silt loam

Third Class Soils

The Third-class soils are physically fair soils; they are poor to fair for crops that require tillage, and fair to very good for permanent pasture.

Each is characterized by a workability, conservability, or productivity that singly, or in combination, is sufficiently poor so that the physical suitability for tilled crops is definitely limited. These soils physically are better suited than Fourth-class soils to crops that require tillage, but less well-suited than the Second-class soils. Factors that limit physical suitability for crops that require tillage include low content of plant nutrients, low content of organic matter, low water-holding capacity, undesirable texture, structure, or consistence, strong slope gradient, stoniness, erodibility, chertiness, or inadequate natural drainage. Because of the diversity of characteristics among the soils, the management requirements range widely.

Examples of Third-class soils in the state include:

Baxter cherty silt loam
Burgin silty clay loam
Calloway silt loam
Clarksville cherty silt loam
Decatur silty clay loam, eroded hilly phase
Dulac silt loam
Falaya silt loam
Hatchie silt loam
Ina silt loam
Leadvale silt loam
Monongahela very fine sandy loam
Needmore silt loam
Olivier silt loam
Talbott silty clay loam, eroded phase

Fourth Class Soils

The Fourth-class soils are physically poorly suited to crops that require tillage and are poor to very good for permanent pasture. They are considered as poor soils mainly because of the limited uses to which they are well suited. On some farms, however, where permanent pasture is desirable, some of these soils may be very important.

Each soil of this group is so difficult to work or to conserve, or both, that it is not ordinarily feasible to use the management practices necessary for the production of tilled crops. On some farms, however, soils that are well suited to row crops may be so limited that intensive soil management is necessary for the successful use of Fourth-class soils for these crops. They are generally used for pasture on farms where an adequate crop acreage is available. A considerable acreage is used for crops, however, on farms where the areas of soils better suited to the purpose are too small to satisfy the needs of the farm unit. The intensity of management now practiced on areas of Fourth-class land in crops is generally inadequate for good soil conservation. As with Third-class soils, the management requirements vary widely, both for crops that require tillage and for pasture.

Some examples of Fourth-class soils of the state include:

Almo silt loam

Atkins silt loam

Baxter cherty silt loam, hilly phase

Beechy silt loam

Bodine cherty silt loam, hilly phase

Calhoun silt loam

Clarksville cherty silt loam, hilly phase

Dandridge silt loam

Dellrose cherty silt loam

Dulac silty clay loam, eroded phase

Dyer silt loam

Fullerton cherty silty clay loam, eroded hilly phase

Greendale silty clay loam, eroded slope phase

Guthrie silt loam

Lee silt loam

Melvin silt loam

Memphis silty clay loam, eroded hilly phase

Prader silt loam

Purdy silt loam

Robertsville silt loam

Tyler silt loam

Waverly silt loam

Fifth Class Soils

The Fifth-class soils consist of soils or land types that are very poorly suited to crops that require tillage, and very poorly suited to permanent pastures. They are so difficult to work and conserve, or so low in productivity, that their use for tilled crops is very impractical. Many are so steep, rocky, or gullied that operational activities, such as liming, fertilizing, mowing and seeding, are nearly impossible even for permanent pastures. Some of the soils are so shallow to bedrock that only a limited growth of grass vegetation may be expected. Under present conditions these soils or land types apparently are better suited to forest or similar uses.

Some examples of Fifth-class soils include:

Bodine cherty silt loam, steep phase
Clarksville cherty silt loam, eroded steep phase
Dandridge silt loam, steep phase
Dellrose cherty silt loam, steep phase
Gatlinburg silt loam, steep phase
Lexington-Ruston complex
Litz silt loam, steep phase
Memphis silty clay loam, severely eroded steep phase
Muskingum stony loam, steep phase
Ramsey fine sandy loam, steep phase
Rough mountain land
Rough stony land

Comparison of Two Land Classing Methods

This classification is very similar to but less detailed than the classification used by the Soil Conservation Service which groups all soils in eight capability groups (13). Land classes one, two and three are practically the same as the land capability classes one, two, and three of the Soil Conservation Service. Land class four includes land capability classes four, five and six; and land class five includes land capability class seven and a portion of land capability class eight.

Consequently, the difference between the two classifications is very slight and in some cases the two systems might be used interchangeably.

Purpose of Land Classification

The purpose of a land classification is to aid in properly utilizing the land in the manner to which it is best adapted under the prevailing conditions. The farms of Tennessee vary in size from 10 acres or less to a thousand acres or more. The pattern of soils, slopes, erosion and other factors, vary from one farm to another to such an extent that it is impossible to set forth any definite rules of land use that will exactly fit every farm. Most farms require a certain acreage of row crops, sod crops, permanent pasture and forest, to round out a balanced farm program.

Since so many uses are made of the land on an individual farm it is imperative that the land be classified for such uses and then further classified for its adaptability to individual crops or groups of crops. Land best suited for row crops is the nearly level, well drained areas that are easily worked, easily conserved and highly productive. The intensity of its use for row crops will depend upon how nearly the soils fit such a grouping. As land becomes more difficult to conserve, the rotation of row crops and sod crops must be more carefully selected, and a longer interval between row crops will be required. Lands that are very difficult to conserve and work, especially those of low productivity, are usually utilized for permanent pastures and those not suited for pasture, due to erosion, stoniness or depth, are utilized for forest.

CHAPTER III

SOIL AMENDMENTS

The purpose of soil amendments is to encourage more vigorous crop growth. Amendments include anything that is used to stimulate such growth. Their use aids in controlling nutrient balance and availability by supplying the essential elements the plant needs or by improving soil tilth.

Soil amendments available for use in soil management in Tennessee are: (1) Organic matter, (2) lime, and (3) fertilizers.

A soil's need for amendments depends upon its use, extent of erosion and natural productivity. Soil amendments seldom are recommended or required for forests but are needed on most soils for pastures, field crops and truck crops. The amount and type of amendments needed vary with the fertility level and tilth of the soil and the type of plants grown. A large percentage of the soils of Tennessee are now deficient in organic matter; many require lime and most of them require fertilizers for efficient crop production. The soils of Tennessee usually need application of soil amendments in the following order: (1) Lime carrying both calcium and magnesium to control soil acidity and to increase the availability of phosphate and nitrogen and to increase decay of organic matter; (2) phosphate to increase growth and production of legumes and grasses; (3) nitrogen to stimulate growth of grasses, small grains, and increase bacterial activity in the soil; (4) potassium is needed for legumes and high yields of tobacco, corn, potatoes and hay crops; (5) minor elements in special cases, for example boron on alfalfa and other legumes.

The above statements are general and are subject to many exceptions. Generally the soils developed from shales in East Tennessee are less deficient in potassium than other soils of the state. Nearly all the soils are deficient in phosphorus except the Maury, McAfee, Mimosa, Braxton, Mercer, Culleoka, and Dellrose soils of Middle Tennessee which are medium to very high in available phosphorus.

Organic Matter

Organic matter functions three ways in the soil, viz., chemically, physically, and biologically. First, organic matter is a chemical source of important plant nutrients which are slowly released (18). Second, physically, organic matter improves tilth conditions which affect such things as moisture holding capacity, moisture infiltration, and air insulation (30). These improvements are due to the promotion of granulation which is manifest by a decrease in tendency to form clods, and the greater ease with which the soil may be worked with tillage implements. Third, organic matter is a source of food for the large population of soil micro-organisms. The combined activities of the micro-organisms influence the availability of many plant nutrients, particularly nitrogen, phosphorus, and sulphur.

There are three main sources of organic matter. These are: (1) barnyard manures, (2) leguminous and non-leguminous green manures, and (3) mature crop residues. In any good program of organic matter maintenance, these are not treated as alternatives, but each is made use of in its proper place as often as possible. Each has its own special qualities and each supplements the other.

Barnyard manure when added to the soil has a two-fold effect. First, there is an immediate effect because its content of easily available nutrients that causes a yield increase in the first crop. Second, there is a long-time effect due to slow decomposition of the more resistant residues that causes a yield increase in succeeding crops.

The leguminous and non-leguminous green manures include the winter-grown and summer-grown clovers as well as green crops of small grains or grass. The leguminous plants are best suited for green manures. A well nodulated legume crop may contain from 50 to over 100 pounds more of nitrogen per acre than is taken directly from the soil, and the reserve soil nitrogen may be increased by such an amount if the crop is turned under. Leguminous green manures are more effective in increasing the organic matter content of the soil than non-leguminous green manures. Most green manure crops do not exhibit the slower, long-time effect to the extent that barnyard manure does. This may be due to the fact that immature tissues, on decomposition, leave only a small resistant residue.

The value of above ground crop residues does not depend entirely on the conservation of plant nutrients which they contain. Possibly just as important is the fact that these residues are mature material which on decomposition may leave appreciable amounts of relatively resistant residue in the soil.

Grass sod, though it is not exactly a crop residue, provides possibly the best means of organic matter renewal. Erosion losses are prevented and biological activities are, for the time, no longer interrupted by cultivation. The actual mass of roots per acre is very large and the distribution is such that on decomposition the physical properties of the soil seem much improved.

Though additional minerals are made available through the incorporation of organic matter the soil supply cannot be increased by turning under green manures and crop residues. Plants can return to the soil only the minerals they obtained from the soil. The only exception is the nitrogen which inoculated legumes may obtain from the air.

To attempt to build up a large supply of organic matter is not practical. Organic matter functions mainly as it is decayed and destroyed. The objective should be to have a steady supply of organic matter for the benefit of the growing crop.

The release of plant nutrients from organic matter is governed by conditions which favor or retard the growth and development of the microbial population of the soil. Favorable conditions of moisture supply, temperature and air hasten the process. On the other hand, the process is retarded by an over or under supply of moisture, by low temperatures, or by a limited supply of air.

Fertilizers

The primary objective in the use of fertilizers is to supply plant nutrients to growing crops. Although a crop is fertilized it is still dependent upon the soil for a large portion of its nutrients. Thus, fertilization applications may be considered as supplementing the supply of nutrients contained within the soil.

Besides using fertilizer to stimulate crop growth and increase yields, it should be used to establish a proper balance between the necessary elements of plant nutrition. This balance is necessary to prevent over or under stimulation of growth of the crop at the possible expense of profitable yields. In addition to increasing availability of plant nutrients and stimulating crop growth, fertilizers influence the soil micro-organisms in much the same way as they do the crop.

Plants require at least eleven nutrient elements from the soil (11). The elements most commonly applied as fertilizers are nitrogen, phosphorus, potassium, calcium, magnesium, and minor elements such as boron. These may be applied as complete fertilizers or applied separately. Most commercial fertilizers consist of varying proportions of nitrogen, phosphate, and potash. Although much lime is applied, it is not commonly thought of as a fertilizer, though as a source of calcium and often magnesium it does influence plant nutrition. Sulphur is an element not commonly applied separately though it is essential. In many areas the rainfall supplies ample quantities for plant needs. The need for fertilizers varies with the fertility levels of the individual soil types and the feeding characteristics of the plants to be grown.

The need for various fertilizer elements in Tennessee are: (1) Lime, to control soil acidity; to increase the availability of phosphate; to hasten the rate of production to decay of organic matter, and to increase the availability of nitrogen; (2) phosphorus, to supplement the low soil supply; (3) nitrogen, to aid in the decomposition of organic matter; to increase soil biological activities and stimulate growth of non-leguminous crops. Often both legumes and commercial nitrogen are needed to obtain maximum growth of such crops as corn, cotton, and tobacco. (4) Potassium, and (5) minor elements, such as boron for the production of alfalfa and other clovers, and certain truck and fruit crops.

Soil Reaction

Soil reaction refers to the relative acidity (sourness) or alkalinity (sweetness) of a soil (40). The pH scale has been accepted as a simple measure. At pH of 7.0 a soil is neutral, neither acid nor alkaline. As values decrease from pH 7.0 soil acidity increases, and as they rise above pH 7.0 the soil alkalinity increases.

Tennessee soils range from about pH 4.0, strongly acid, to pH 7.5, slightly alkaline. The average surface soils under cultivation in the state originally had a pH of 5.0 to 5.5, (medium acidity). Leaching of certain plant nutrients such as potassium, following application of certain fertilizer salts, is in general a little more severe from strongly acid soils than from those that are slightly acid to neutral.

The desirable range of soil reaction is pH 6.0 and 6.5 in Tennessee soils for most crops. Care should be taken to prevent raising the pH above 7.0 because the availability of boron and some other minor elements is lower at high pH levels. The availability of phosphorus increases with the pH from strongly acid to the slightly acid range. Availability of phosphorus decreases with rise of pH above the very slightly acid or neutral range. The average Tennessee soil requires about two tons of ground limestone to change the soil reaction one pH unit.

The most practical method of determining the soil reaction is by a soil test. The most accurate method is with a glass electrode and potentiometer. This is one of the services rendered by the soil testing laboratory and it is suggested that it be used where practical to determine the needs for lime. However, quick test methods using indicator dyes, though less accurate, are often satisfactory.

It should be borne in mind that although an optimum pH for any plant may be determined for a given set of conditions, many plants are capable of good growth throughout a moderately wide range of acidity. This is particularly true if mineral nutrients and organic matter are present in relative abundance (11).

Lime

Lime is added to the soil primarily to correct acidity, although it has other effects. Agricultural lime is not ordinarily considered as a fertilizer, even though calcium, one major constituent of lime, and magnesium, an important constituent in dolomitic limestones, are both plant nutrients. Much of the good effect of lime on acid soils must be attributed to the available calcium and magnesium furnished to plants.

Lime is an inexpensive material yet it is quite effective in improving crop yields, as indicated by the data in Tables III, IV and V.

TABLE III

RESPONSE OF COTTON TO LIME*

Treatment	Yield
Fertilized with 200# superphosphate and 50# muriate of potash	1413# seed cotton/A
Same as above plus lime	1574# " "
Increase	161# " "
% increase	11.4% " "

* Unpublished data from West Tennessee Agricultural Experiment Station at Jackson, Tennessee

TABLE IV

EFFECTS OF LIME ON CROP YIELDS IN A 5-YEAR ROTATION OVER A 30-YEAR PERIOD (1909-1939)*

Crop	Average annual increase in yield from liming
Soybean hay	1/2 T
Barley	1 1/5 Bu.
Clover and grass	4/5 Ton
Irish potatoes	14 Bu.
Corn	6 "

* Unpublished data of West Tennessee Agricultural Experiment Station at Jackson, Tennessee.

In the study summarized in Table IV lime was applied at the rate of 2 tons every 10 years. Liming showed a gross profit of $158.00 per acre for the entire period after deducting cost of liming.

Data from the Middle Tennessee Experiment Station as given in the Tennessee Agricultural Experiment Station Annual Report for 1944 show the detrimental effects of over-liming eight years previously.

Rate of Liming	Corn Yields	Oat Yields
2 Tons lime/A	29 bu./A	26.8 bu./A
8 Tons lime/A	------	13.7 bu./A
10 Tons lime/A	2.5 bu./A	

Lime causes the precipitation of soluble aluminum and iron and thereby increases the availability of phosphates and particularly applied phosphates. Neubauer studies by MacIntire and Hatcher (20) show that pre-liming the soil to a pH between 6.0 and 7.0 increased phosphate intake in all cases. These data would indicate that increased yields from crops could be expected from pre-liming the soil to the above pH.

The use of lime may also increase the need for other elements as a result of increased vegetative growth and the need for the maintenance of the nutrient balance within the soil.

Rules for Use of Lime

Liming materials available for use in the state are; ground calcic limestone ($CaCO_3$), ground dolomitic limestone $Ca(Mg)(CO_3)2$, calcium silicate slags, ($CaSiO_3$), burned lime, (CaO) and hydrated lime $Ca(OH)_2$. Ground limestone should be 90% calcium carbonate ($CaCO_3$) equivalent, and should be ground fine enough to pass a 10-mesh sieve.

There are two sources of calcium silicate slag for liming purposes, (1) a by-product of the TVA phosphate plant at Muscle Shoals, Alabama, which is very satisfactory and usually tests from 70 to 75% calcium carbonate ($CaCO_3$) equivalent; and (2) a by-product of the Monsanto Chemical Company phosphorus plants, which has not been satisfactory, due to its low purity and solubility.

Other forms of lime which may be locally available should be used according to their calcium carbonate equivalent and fineness (7)(17).

Avoid the use of too much lime and reduce dangers of overliming injury as shown by above data from Middle Tennessee Agricultural Experiment Station.

Lime may generally be applied at any season of the year at the convenience of the farmer. However, in the case of rotations including tobacco and Irish potatoes, the lime should be applied after harvest. If practical, all liming should be done six months to one year ahead of planting and fertilizing such crops as alfalfa and red clover.

Broadcast lime uniformly over the ground surface and mix in the surface three or four inches of soil except in cases where there is a sod already established. It is not often practical to mix lime with the surface when applied to permanent pasture sods (32).

The downward movement of lime depends upon many factors (31):

(1) Lapse of time. Regardless of the amount of lime applied to a layer of soil, a considerable period, usually several years, must pass before a layer a few inches lower will be affected.

(2) The amount applied. Much more rapid and greater penetration will occur from initial heavy applications than from small increments.

(3) Placement. The deeper the placement or incorporation of lime with a soil the greater will be the penetration effects on the soil, and also the greater the possibility of its moving downward beyond the zone of the plant roots.

(4) Physical and chemical characteristics of the soil. The downward movement of lime will be greater in sandy than in clay soils and in neutral than in acid soils.

(5) Climate. More penetration may be expected with increasing precipitation.

(6) Kind of lime. Dolomite resists solution more than calcite and, of course, burnt and hydrated limes react with the soil more quickly than limestone. However, in a few years after application, differences in the effects on the soil of the various kinds of lime are usually quite negligible.

(7) Crops on land and other fertilizer applied. Alfalfa removes approximately six times as much lime as timothy and ammoniacal fertilizers deplete the calcium oxide (CaO) content of a soil by about fifty pounds for each unit (20 pounds) of nitrogen.

The frequency of liming depends upon the rate of removal by leaching and the rate of removal by crops (25). Under Tennessee conditions leaching removes 200 pounds or more calcium per acre per year. The average crop removal is about 20 pounds per acre. The best and most accurate method of determining the need for reliming is to have the soil tested. In the absence of testing, a good rule is to relime with about one ton per acre every five to ten years, depending upon the type of crops grown.

Phosphate

With the exception of areas in the Central Basin of Middle Tennessee occupied by the Maury, McAfee, Loradale, Braxton, Donerail, Mercer, Mimosa, and Dellrose soils series, most of the soils of Tennessee are naturally low in available phosphates. Those listed above are medium to very high in phosphate and give little or no response to applications of this element. Exceptions to these are small areas in West Tennessee and some bottom soils.

Phosphorus tends to counteract and balance the effects of an excess of nitrogen, particularly by increasing resistance to disease (11). Many functions of plants cannot be carried on in the absence of sufficient phosphorus. Phosphorus encourages blooming and the setting of seeds, and hastens maturity. Phosphorus encourages the development of fibrous roots of crops, especially of such fall-seeded ones as wheat or oats. This effect enables the crop to withstand winter-killing and to make rapid early spring growth (11).

Phosphorus, by balancing the unfavorable conditions created by an excess nitrogen, strengthens the straw of cereals and thus reduces the tendency toward lodging. Seeds are relatively rich in phosphorus, and an addition of it, therefore, increases yields.

Phosphorus improves the vigor of plants and finally the feeding quality of the crop.

No undesirable effects even from heavy applications of phosphorus have been noted (26).

Phosphorus materials available for use as fertilizers include:

Material	Available P_2O_5
Superphosphate	16% - 20%
Fused tricalcium phosphate	27%
Triple superphosphate	45% - 47%
Calcium meta-phosphate	63%
Precipitated phosphate	32%
Basic slag	10%
Raw phosphate rock	2% - 5%
Colloidal phosphate	2% - 4%
Raw steamed bone meal	22% - 25%

Unpublished data obtained from TVA Cooperative Experiments by the Tennessee Agricultural Experiment Station indicate that the various phosphates are variable in their efficiency. The Table VI indicates the relative efficiency of selected phosphates as compared to standard superphosphates.

The cotton comparisons were made on Dexter, Grenada and Loring soils. The corn comparisons were made on Memphis, Hymon, Leadvale and Emory soils.

Recent studies of crop response using radioactive phosphorus isotopes as tracers reported in a news release by the U. S. Department of Agriculture (1/8/48), indicate that potatoes took up phosphorus during the whole growth period. Over 50 percent of phosphorus in a potato crop grown on soil of low fertility came from the fertilizer. Corn, cotton, and tobacco on the other hand utilized applied phosphates chiefly during early growth. Young corn plants in fertilized soil were much larger than

TABLE V

RELATIVE AVERAGE YIELDS PRODUCED BY SUPERPHOSPHATE IN COMPARISON WITH NO FERTILIZER AND ORDINARY 16 PERCENT OR 20 PERCENT SUPERPHOSPHATE ON UNLIMED AND LIMED SOILS (2)

Treatment	Unlimed		Limed	
	No. of tests	Relative yield	No. of tests	Relative yield
No fertilizer	650	64.5	200	77.5
N and K only	3,654	79.9	984	81.4
16% or 20% superphosphate with N & K	3,943	100.0	1,432	111.0
43% superphosphate with N & K	3,138	98.0	2,920	106.1
43% superphosphate with N & K and sulphur	1,292	100.9	No	data

TABLE VI

RELATIVE EFFICIENCY OF VARIOUS PHOSPHATES
IN A COMPLETE FERTILIZER (32-40-50)

Kind of Phosphates	Average four Fields cotton	Average four Fields corn
Standard superphosphates	100	100
Triple superphosphate	97	94
Fused tri-calcium-10 mesh	94	93
Fused tri-calcium-40 mesh	93	95

* Unpublished data from TVA Cooperative Experiments, West Tennessee Agricultural Experiment Station at Jackson, Tennessee.

those in unfertilized soil, but this difference disappeared as the plants matured. At the end of the growth period less than 20 percent of the phosphorus in the corn plant had come from the fertilizer.

The findings indicate that differences in crop response to applied phosphates were due in part to differences in the character of the root systems. With limited roots, potatoes depended on a concentrated supply of fertilizer. Young corn obtained its phosphorus from the fertilizer but as the plant developed a larger root system it was able to utilize the native phosphorus of the soil. Both tobacco and cotton absorbed smaller amounts of fertilizer phosphorus as their root system developed.

Nitrogen

The need for nitrogen is closely related to the utilization of legumes and organic matter. Inoculated leguminous crops are capable of obtaining a portion of their nitrogen needs from the soil air. Soybeans may obtain as much as 40 percent of their nitrogen from the air.

Nitrogen acts quickly within the plant. A crop quickly changes to a dark healthy green following the application of moderate quantities of available nitrogen (11). Nitrogen stimulates the growth of both leaf and stem, the so-called "vegetative" parts of the plant. An abundance, particularly an excessive supply, of nitrogen produces a watery, succulent growth, a type of growth desirable in leafy vegetables, such as lettuce and spinach, but very undesirable in grains and some fruits. Grains tend to have long, weak straw, and to lodge badly very early, as a result of large supplies of nitrogen, especially if the supply of moisture also is excessive.

Because of this quick action of nitrogen, even lightly fertilized crops may show response to fertilization in the form of increased vegetative growth. Nitrogen from the soil organic matter does not affect the crop so early as does available inorganic nitrogen that is applied at seeding time or as a top dressing. Often the grain crop that is fertilized with phosphorus alone catches up later in the season and outyields that which was stimulated by the small amount of nitrogen in the complete fertilizer applied to the grain. The early effect of nitrogen may mislead the farmer who makes no comparison of actual yields but who depends entirely on the appearance of the crop.

Excessive use of nitrogen may have several detrimental effects. It may delay ripening of fruits, vegetables, and other plants that produce ripe seed, and such delay sometimes results in damage from frost. Excess nitrogen produces poor quality in peaches. The wood of this tree is sensitive to winter injury, and this is particularly true if its maturity is delayed by an excessive supply of nitrogen. The lodging of grains resulting from excess nitrogen reduces the yield and quality of harvested grain. Such grain often is "chaffy". Finally, too much nitrogen, particularly if accompanied by abundant moisture, appears to lessen the resistance of plants to disease. For all these reasons the use of nitrogen to excess is to be avoided.

Nitrogenous materials for fertilizer use are obtained from organic and inorganic sources (7).

Sources of organic nitrogen include cottonseed meal containing 6.7 to 7.4 percent nitrogen; fish scrap or dried fish tankage containing 5 to 7 percent nitrogen; dried blood containing from 8 to 14 percent nitrogen and pulverized manures containing 2 to 6 percent nitrogen. These materials contain varying percentages of both phosphate and potash. The organic sources of nitrogen are more slowly available than the inorganic sources.

The inorganic sources of nitrogen include: Nitrate of soda containing 16 percent nitrogen; sulphate of ammonia containing 20 percent nitrogen; calcium nitrate containing 17 percent nitrogen; ammonium nitrate containing 32.5 percent nitrogen; aqua ammonia containing 24.7 percent nitrogen; anhydrous ammonia containing about 82 percent nitrogen; cyanamid containing about 21 percent nitrogen and urea containing about 46 percent nitrogen.

Relative effectiveness of various sources of nitrogen in fertilizer mixtures on corn as reported by the Pee Dee Experiment Station, South Carolina, 1920-1925 are shown below:

Nitrate of soda	=	100.0
Ammonium sulphate	=	97.5
Dried blood	=	93.9
Fish scrap	=	84.0
Cyanamid	=	85.4
Cottonseed meal	=	82.0

Potash

The proper quantity of available potash along with a goodly supply of the other elements improves tone and vigor and produces healthy growth (11). By balancing the effects of nitrogen, potash improves the natural resistance of plants to disease. In contrast, potash in common with nitrogen delays the ripening of many crops. In this respect, the effect of potash counteracts that of phosphorus. Potash is required for the formation of chlorophyll. With energy from the sun, chlorophyll produces starch for which action potash is essential.

The Tennessee soils vary materially in their content of readily available potash; the amount present very often depends upon the type of crops grown on the soil and the disposition of these crops. Legumes are heavy consumers of potash, and lands which have produced legumes, particularly for hay crops, are apt to be more deficient than those used for other crops less demanding of potash. Liming will repress somewhat the outgo of potash from the soil in drainage water. Deficiency symptoms of potash have been observed on crops grown on many soils following liming.

Common sources of potash materials for fertilizer use include muriate of potash containing 50 to 60 percent potash; sulphate of potash containing about 50 percent potash; sulphate of potash magnesia containing about 25 percent potash and manure salts containing about 25 percent potash (7).

Minor Elements

Trace elements or minor elements are not generally a problem at this time in Tennessee except for boron. These trace elements include boron, copper, zinc, magnesium, manganese, and iron. They are necessary for optimum plant growth. Tennessee soils are apparently well supplied as yet. Even boron was not a factor in crop production until the practice of liming became common (24). Then deficiencies of boron began to appear on alfalfa. Liming represses or reduces the availability of boron in the soil. Boron deficiencies may affect production of other clovers, tobacco, cabbage, lettuce, beets and apples, but, with the exception of alfalfa, has not been a major problem so far. Only small amounts are needed to correct the deficiencies, and care should be exercised to prevent over-dosage. An excess amount applied to the soil may do more harm than good.

Nutrient Deficiency Symptoms

Plants suffering from nutrient deficiencies or unbalance indicate the condition to the grower by symptoms of color or growth characteristics that are comparatively easy to interpret (14).

An excess of nitrogen is indicated by a dark green color, elongated stems and sometimes lodging, particularly in small grains.

A deficiency of nitrogen will be indicated by a yellowish green or light green appearance, which finally develops into firing and necrosis or death of leaf tissue. Stunted growth also is an indication of nitrogen deficiencies.

An excess of calcium or lime is indicated by retarded root growth, delayed maturity and symptoms characteristic of phosphate or potash deficiencies (14).

Deficiencies of phosphate are indicated by a stunted growth, and a purpling of the leaves or blades of young plants. No symptoms have been observed resulting from an excess of phosphate.

Potash deficiency symptoms are indicated by a yellowing or burning along the edge of leaves and blades of plants. Weak stalks and lodging are also symptoms of potash deficiency.

Commercial Fertilizers

For optimum plant growth there must be a balance of nutrients present in the soil. Most Tennessee fertilizer formulas are in the proportions of 0-1-1, 0-2-1, 1-2-1, 1-3-2, 1-2-2, 1-6-3 of nitrogen, phosphate and potash respectively. Some grades sold in the state include 0-14-7, 0-12-12, 2-12-6, 3-9-6, 4-8-8, 4-12-4, and others. In past years the number of grades mixed numbered over one hundred, but during and since the war there has been an effort to hold the number down to 12 or 15 grades (7).

To determine the need for commercial fertilizers or fertilizer elements, with relative accuracy, one must evaluate, (1) the soil parent material; (2) the soil physical properties including soil permeability, soil depth, prevailing slopes and soil water-holding capacity; (3) the organic matter levels; (4) the past soil management; and (5) have soils tested for available nutrients.

In addition to evaluating the soil resources, consideration should be given to differential crop responses to certain plant nutrients as well as the economic value of the crop grown.

Principles of Fertilization

The kind of fertilizers to use depends upon the results of soil tests, crop needs and soil responsiveness. The crop needs will vary with the length of growing season and the type of root development.

The amount of fertilizer to use depends upon the analysis or concentration and the method of distribution. A low analysis material will require heavier application to give the required amount of plant nutrients than a higher analysis material (17). Also, in general, the higher the analysis the lower the unit cost of plant nutrients. Fertilizers applied broadcast require two to three or more times as much material as row or drill applications. The method of application will also depend upon the root growth habits of the crop. Potatoes, with their small root system concentrated in a limited area, respond better and give more efficient growth if the fertilizers are applied in the drill or in narrow bands on each side of the drill row. Corn, tobacco and cotton, even though planted in rows, have a more spreading root system and will feed on row applied fertilizers mainly during early plant growth. Crops sown broadcast or permanent pastures require broadcast applications for efficient results.

Fertilizers should be applied as nearly as possible at planting time for row crops. On broadcast crops apply fertilizer during the seedbed preparation, probably at the last disking of the seedbed. Nitrates should be applied at the time the plant will make the most use of them; thus, side-dressing is often preferred instead of at planting time. With ammonia satisfactory results may be obtained if applied at planting time, as it is more slowly available than the nitrate form of nitrogen.

To prevent undue fixation before the plants can utilize the material, phosphate should be applied at planting or during seedbed preparation (26). Potash should not be applied in excessively large applications but enough for about one year's growth. More than this may cause luxury feeding by the plant. Pasture and hay crops in general need large phosphate applications to supply plants for three to five or more years.

Sulphur is not ordinarily needed as a fertilizer in Tennessee. A sufficient amount is obtained in the rainfall for most Tennessee crops.

Fertilizer should be used for a profit. Use it heavily on cash crops and the more responsive crops.

Effects of Fertilizer Materials on Soils

Some fertilizer materials such as sulphate of ammonia leave in the soil an acid residue (11). Others tend to make the soil alkaline. Nitrate of soda and calcium cyanamide have this effect. Nitrate of soda, in heavy applications over a period of years, may cause the soil to puddle or become cloddy. This puddling is the effect of the sodium residue. Presumably, in time, the acidifying fertilizer materials will have a bad effect on the structure of the soil because of the removal of calcium (2).

Determinations have been made of the limestone equivalent of the alkaline effect per ton of fertilizers which supply basic materials, and of the limestone required to neutralize the acid effect of those which tend to produce an acid condition of the soil. The nitrogenous fertilizer materials tend to lower the pH of the soil. The limestone equivalents from the standpoint of acidity and alkalinity effects of many fertilizer materials are given in Table VII (11).

TABLE VII

PERCENTAGES OF PLANT NUTRIENTS IN FERTILIZER
MATERIALS AND RESIDUAL EFFECTS UPON THE SOIL

Material	% Nitrogen	% Phosphoric Acid	% Potash	Reaction	RESIDUAL EFFECT ON THE SOIL: Limestone required for neutralization of residual acidity from 1 ton of fertilizer materials* lbs.	RESIDUAL EFFECT ON THE SOIL: Limestone equivalent of residual alkalinity from 1 ton of fertilizer material-lbs.
Ammonium Nitrate	35			acid	1,250	
Calcium nitrate	15			slightly alkaline		400
Cal - nitro	20.5			neutral	---	---
Cottonseed meal	6-9	2-3	1.5 - 2.0	slightly acid	200	
Cyanamide	22			alkaline		1,260
Nitrate of soda	16			alkaline		583
Sulphate of ammonia	20.5			acid	2,249	
Basic slag		10		alkaline		1,015
Calcium metaphosphate		63		----	----	----
Superphosphate		16-45		neutral		
Muriate of potash			50-60	neutral		
Sulphate of potash			48-52	acid	----	----

* Pierre, W. H., "Determination of Acidity and Basicity of Fertilizers." Jour. Ind. En. Chem., Vol. 5, p. 29, 1933.

CHAPTER IV

WATER CONSERVATION

A study of rainfall in the state indicates that in the 52-year period between 1886 and 1938, the mean precipitation varied from a low of 39.8 inches to a high of 59.8 inches in 1929. The highest monthly precipitation came in March with 5.41 inches and a low mean of 2.82 inches in October. The annual mean precipitation is 49.92 inches. The highest seasonal mean precipitation is in the spring with 14.02 inches and the lowest in the fall with a mean precipitation of 9.49 inches.

Even though the total mean precipitation is 49.92 inches, it varies in different geographical areas of the state. The average precipitation of different geographical areas is shown below (42):

West Tennessee	average	annual	precipitation	= 49.10	inches
Central Basin	"	"	"	= 50.74	"
Highland Rim	"	"	"	= 52.20	"
Cumberland Plateau	"	"	"	= 55.13	"
East Tenn. Valley	"	"	"	= 48.32	"
East " Mountains	"	"	"	= 53.15	"

These average figures are from rainfall measurement stations with from 13 to 40 year records (42).

From the above data Tennessee should theoretically have sufficient rainfall even in the drier years to produce satisfactory crop yields. In practice, however, such years of low rainfall result in reduced pasture and crop yields.

The lowest rainfall of the year usually comes during the late summer and fall months, the same period that certain plants need water to mature. During the same period the rate of evaporation and respiration is the highest, which probably accounts for greater water loss than run-off. This combination of water losses together with low rainfall often result in inadequate supplies for maximum production.

There is nothing that the farmer can do to increase or decrease the amount of rainfall. However, by wise selections of crops that are adaptable to the prevailing conditions of rainfall and soil conditions he can take advantage of and make the most use of the prevailing rainfall conditions. Soils vary in their water-holding abilities according to the development of their physical characteristics. Therefore, by placing winter and spring growing crops on land that is droughty in summer greater production may be obtained than from summer-growing, drought sensitive crops. The production of small grains would be preferable to corn on soils underlain by hardpans or clay pans; likewise drought resistant crops such as soybeans, sorghums and cotton may produce better than corn or similar crops on droughty soils.

On soils of poor internal drainage shallow rooted legumes such as white clover and alsike clover together with grasses such as redtop and fescue often are better adapted and will likely produce larger economic returns over a period of years than soybeans, cotton, or sorghum.

Rainfall properly distributed throughout the growing season of crops is a factor of major importance. On the Cumberland Plateau the distribution is more uniform than in any other portion of the state.

Under these conditions crop yields are good even though the natural fertility of the soils are low. On the other hand, the Central Basin Area is much higher in fertility but suffers more frequently from drought and the yields are lower.

Water run-off from rainfall is harmful and destructive if uncontrolled, particularly under fallow and cultivated conditions; the water is quickly loaded with soil material which is washed down the slopes and often carried away in the streams. The soil and plant nutrient losses under varying conditions of cover and culture are indicated by the data in Table VIII (33).

The data covers the 5-year period 1941-1945, when rainfall averaged 42.2 inches. The plots were 90 feet long on 3% slope and farmed up and down slope. All plots were limed and an 0-20-10 fertilizer was used with the small grain except as noted.

TABLE VIII

SOIL LOSS IN TONS PER ACRE AND AS A PERCENTAGE OF THE LOSS UNDER CONTINUOUS CORN FOR 22 CROPPING SYSTEMS (33)

Rotation	Crop or Residue Returned	Soil loss Tons/A	Soil loss %
Continuous corn (no treatment)	None	17.0*	100
Corn, oats (no treatment)	Corn stalks	10.0	59
Corn, corn, oats, wheat and sweet clover	1st corn stalks and sweet clover	6.6	39
Corn, oats and sweet clover	Corn stalks & sw. cl.	4.9*	29
Corn, wheat & sweet clover	Sweet clover	4.7*	28
Corn, corn, oats, grass legume hay +	All corn stalks	4.2*	25
Corn, wheat, sweet clover, timothy hay	Stubble only	3.4	20
Corn, wheat, grass legume hay 1 year +	" "	2.2	13
Corn, wheat, grass legume hay 2 years +	" "	1.9	11
Corn, wheat, grass legume hay 3 years +	" "	1.9	11
Drill soybean hay, wheat, lespedeza, lespedeza, corn	" "	6.2	36
Drill soybean hay and winter barley grazed annually	" "	5.2	31
Row soybean grain, rye, grass legume hay, corn	Soybean straw and corn stalks	4.3*	25
Row soybean grain, rye, grass legume hay +	Soybean straw	2.7*	16
Drill soybean hay, winter barley, grass legume hay +	Stubble only	1.4	8
Oats hay and grazed lespedeza (annually)	" "	3.6	21
Wheat and lespedeza both grazed (annually)	" "	2.6	15
Oats and lespedeza both for hay (annually)	" "	2.5	15
Wheat grain and lespedeza hay (annually)	" "	1.8	11
Rye, grass legume hay grazing 2 yrs.	" "	0.8*	5
Timothy and lespedeza continuously	" "	0.6	3
Timothy, lespedeza & sweet clover continuously	" "	0.4	2

* These soil losses computed from sequence study data; other losses are direct measurements.

+ Mixture of timothy, redtop, red and alsike clover, and lespedeza.

The data show that intensely cultivated crops, such as corn, are more conducive to soil losses than sod crops in rotation with row crops or continuous sod crops.

Erosion results not only in soil destruction but also in soil depletion. Under sheet erosion a portion of the surface and its content of available nutrients are removed.

Vegetation is important as means of erosion control. The sod crops slow down the run-off of water as well as increase the rate of water absorption into the soil. Oats grown after corn reduce the soil loss by 41 percent as compared with continuous corn (Table VIII). As the percentage of sod crops increases in proportion to row crops, the less is the percentage of loss by erosion.

Table IX shows soil losses on various slopes on a Dunmore silt loam under a three-year corn, wheat, and clover rotation (29).

Fertilization aids in water control by stimulating root growth as well as by increasing the surface coverage. The stimulated root growth encourages aeration and absorption of water, thereby reducing run-off. Increased vegetative cover lessens the impact of the falling rain on the soil, thereby reducing compaction as well as retarding the rate of water run-off. All these factors increase the period of time the water is on the land and allow greater absorption.

Table X furnishes data regarding the nutrient supply of the plow layer or surface soil and the percentage lost by sheet erosion during the rotation period (29).

TABLE IX

SOIL LOSSES DURING A 3-YEAR ROTATION 1937 TO 1940 ON 5% TO 25% SLOPES OF DUNMORE SILT LOAM

	Crop Grown	Soil loss, tons per acre from slope of 5%	10%	15%	20%	25%
Average annual loss 1937-40	Corn	3.87	6.37	11.64	11.21	18.55
	Wheat	0.47	1.81	0.77	0.32	0.94
	Clover	0.04	0.07	0.01	0.02	0.01
Loss per 3 yr. rotation		4.38	8.25	12.42	11.55	19.50
Maximum annual loss	Corn	6.47	13.98	24.52	19.74	35.53
	Wheat	0.80	2.74	1.91	1.09	1.89

TABLE X

TOTAL NUTRIENT SUPPLY OF THE SURFACE HORIZON AND PERCENTAGE LOST BY SHEET EROSION PER ROTATION PERIOD OF THREE YEARS ON DUNMORE SILT LOAM

Slope of land %	Total Nutrient Content of the Original Soil Surface Horizon Pounds per Acre				Total soil loss lbs. per A.	Erosion losses per rotation period* % of total nutrient supply (surface horizon) lost			
	N	P_2O_5	K_2O	$CaCO_3$ Equiv.†		N	P_2O_5	K_2O	$CaCO_3$ Equiv.†
5	2,016	2,000	21,728	35,360	8,760	0.6	0.7	0.5	0.5
10	2,304	2,376	21,978	48,420	16,500	1.1	1.0	1.1	0.9
15	2,278	2,091	41,701	30,090	24,840	1.5	1.4	1.5	2.1
20	1,870	1,734	15,606	29,750	23,100	1.8	1.7	1.5	2.3
25	2,142	2,268	18,000	33,300	39,100	2.6	2.6	2.4	2.3
Av.	2,122	2,094	23,803	35,384	22,450	1.5	1.5	1.4	1.5

* Based on average annual losses, 1937-40. Each figure reported is an average of three plots.

† Calcium and magnesium expressed as calcium carbonate equivalent.

A study of the above tables indicates that in controlling water and resultant erosion consideration must be given to the slope of the land with respect to its use as well as to vegetation and fertilization. The losses of both soil material and nutrients were closely related to the slope of the land under conditions of the study cited. These data indicate that as the slope increases, the length of time the land is in sod crops should also increase. Terraces may not decrease the soil losses reported as the results were obtained on 1/50 acre plots, which of course means short slopes of approximately the same length as between terraces.

Surface mulches of straw or similar residue are aids in the utilization and control of water. The mulch protects the soil surface from rainfall impact, slows down run-off, increases infiltration and insulates the soil surface, thus reducing evaporation. Mulches aid in maintaining optimum soil moisture even during drought periods. Mulches that may be available for use on the average farm include straw of small grain, legume and grass residue from seed harvesting operations and clippings from pasture mowing. It is preferable to permit these to remain on the field rather than rake them up and transfer them to another field, except under special conditions for mulching crops such as potatoes and strawberries.

Engineering Methods of Water Control

Mechanical methods of water control are used to reduce the length of slope by erecting soil barriers to impede the downward flow of water. The usual methods applied are contour tillage, contour furrows, contour strip cropping, modified strip cropping, and terraces.

There is often a need for one or more of these measures of erosion control. They are compromise measures in land use. In other words, they are used to permit intensive use of the land without exposing it to excessive soil losses. Their use should be carefully coordinated and integrated with other soil management practices.

Contour tillage is the performance of all tillage operations at a constant level around the slope, or perpendicular to the slope. This method of water control has certain advantages and disadvantages. Among the advantages are: (1) It decreases run-off and erosion; (2) it is inexpensive to adopt; and (3) it requires less power and fuel to perform tillage operations. Among the disadvantages are: (1) The inconvenience on irregular slopes, resulting in rows of irregular length; (2) most farming has been on the square and hence contour cultivation leaves irregular shaped areas in the field that are more or less inconvenient to manage; (3) in most instances point rows are necessary and they add to the inconvenience of operations.

Contour tillage is very important in relation to other methods of water control. It is a "must" operation in connection with contour strip cropping and terraces. These methods used together are very efficient aids to water control on lands used for row crops.

Contouring operations are adapted to any type of soil. The major problem in its use is the character of slope. Uniform slopes lend themselves well to contouring, but complex slopes offer many problems and are not so well adapted to this practice. Under favorable conditions contour tillage alone will reduce erosion losses approximately 50 percent under a row crop culture (16).

Contour furrows are furrows placed on a level around the slope at varying distances for the purpose of impounding water run-off and thus to increase the amount of water absorption into the soil. They are most commonly used in the eastern U. S. and are possibly best adapted to permanent pastures. When used under pasture conditions the outstanding disadvantage is leaving the soil surface rough for mowing.

Contour strip cropping is the alternation of close growing crops or sod crops with row crops across the slope on a level. It may also be defined as growing a rotation in one field in strips on the contour. This method, like contour tillage, is best adapted to uniform slopes.

Advantages of contour strip cropping are the same as contour tillage plus the effects of vegetative strips which aid in reducing the rate of run-off. In addition the strips divide and shorten the slopes exposed to cultivation and which are vulnerable to extensive erosion; they almost force the use of a rotation of row crops and sod crops; they increase the rate of infiltration; and reduce the run-off of water. Some of the disadvantages include the difficulty of utilizing the sod crops for pasture. Farmers in Tennessee who have installed this system report increases in corn yields from 20 to 80 percent in the first rotation over the up and down slope practice for the entire field. Suggested width of strips for unterraced slopes are (21):

Percent Slope	Width of Strips (feet)
2 - 4	100 - 150
5 - 9	75 - 100
10 - 14	50 - 75
15 - 24	35 - 50
25 and up	30 - 35

Modified strip farming is the use of uniformly wide strips of row crops alternating with sod crops, without following the exact contour. It is used and is most applicable in areas of complex slopes which are not well adapted to contour strip cropping. This system does not control water run-off as efficiently as the contour strip cropping method.

Terraces are in effect sidehill, or diversion ditches. Their purpose is to collect water and to carry it at low grade to safe outlets where the concentration can do no damage (23). In laying out a terracing system the first step is locating, establishing, and stabilizing outlets before construction of the terraces. Outlets may be in wooded areas, or grass sods may be established in the outlets where woodlots are not available and the outlet slope is not too steep. Sod forming grasses and legumes are best adapted for this purpose. Under Tennessee conditions Bermuda grass, tall meadow fescue, redtop, bluegrass, and sericea lespedeza are perhaps best adapted for this purpose. For quick growth and establishment of sod, the outlets must be liberally fertilized and seeded from six months to one year prior to terrace construction. Under conditions not adapted to sod or woodlot outlets, particularly under hilly or steep slope conditions, check dams along the outlet are necessary to prevent accelerated cutting of the channel. These dams may be constructed of wood or masonry materials. Masonry materials are more permanent if properly installed.

An evaluation of soil behavior is necessary to determine the type of terrace and its slope. Under hardpan conditions terraces should be closer spaced and allowed just sufficient fall or gradient to remove the water at a rate just sufficient to prevent channel cutting and yet prevent terrace breakage by overflow. Soils without hardpans or clay pans will permit terraces spaced farther apart and with less gradient. Thus the texture and structure of the surface soil and subsoil, as well as the slope of the land, will influence the spacing and gradient of terraces.

Maintenance of terraces to keep outlets open, channels free and banks filled are very necessary to their efficiency and success. If this is done properly for the first year or two after construction, the need for maintenance becomes less critical. Well maintained terraces are aids to both strip cropping and contour tillage.

The Extension Rural Engineers of the University of Tennessee have recommended guide tables for determining the vertical distance between terraces based on the land slope by regions but not by soil types (22). Region 1 is the area west of the Tennessee River; Region 2 lies east of the Tennessee River including the Highland Rim, Central Basin and Cumberland Plateau; and Region 3 includes the East Tennessee Valley. The tables are shown below.

TABLE XI

REGION I

Guide to Proper Vertical Spacing	
Aver. slope in 100 feet	Vertical fall between terraces
3' - 0"	3' - 0"
4' - 0"	3' - 3"
5' - 0"	3' - 6"
6' - 0"	3' - 9"
7' - 0"	4' - 0"
8' - 0"	4' - 3"
9' - 0"	4' - 6"
10' - 0"	4' - 9"
12' - 6"	5' - 4"
15' - 0"	6' - 4"

Above 15' use 50' horizontal spacing

TABLE XII

REGION II

Guide to Proper Vertical Spacing	
Aver. slope in 100 feet	Vertical fall between terraces
3' - 0"	3' - 4"
4' - 0"	3' - 8"
5' - 0"	4' - 0"
6' - 0"	4' - 4"
7' - 0"	4' - 8"
8' - 0"	5' - 0"
9' - 0"	5' - 3"
10' - 0"	5' - 6"
11' - 0"	5' - 9"
12' - 0"	6' - 0"

Above 12' use 50' horizontal spacing

TABLE XIII

REGION III

Guide to Proper Vertical Spacing	
Aver. slope in 100 feet	Vertical fall between terraces
3' - 0"	3' - 8"
4' - 0"	4' - 2"
5' - 0"	4' - 8"
6' - 0"	5' - 0"
7' - 0"	5' - 4"
8' - 0"	5' - 8"
9' - 0"	6' - 0"
10' - 0"	6' - 6"
12' - 0"	7' - 0"
16' - 0"	8' - 0"

Above 16' use 50' horizontal spacing

TABLE XIV

VARIABLE GRADE OF TERRACE

Slopes up to 8%		Slopes 8% to 15%	
Length	Grade	Length	Grade
0 - 100'	0" per 100'	0' - 200'	2" per 100'
100' - 400'	2" " 100'	200' - 600'	3" " 100'
400' - 800'	3" " 100'	600' - 1000'	4" " 100'
800'- 1200'	4" " 100'	1000' - 1200'	6" " 100'

The terrace should be constructed with a ridge and channel large enough to carry the maximum rainfall run-off without breaking over the ridge or cutting the channel. The ridge heights usually range from 15 inches to 25 inches. A broad ridge of these heights will not seriously interfere with machinery operations on or over them. The width of the ridge should be 15 to 35 feet depending upon the need for capacity. On stronger slopes the width often will be even less than 15 feet.

The grade of the channel is often variable. However, on more erosive soils the grade should be less than on less erosive soils, but in all cases the grade should be sufficient to carry away the water slowly and yet not cut the channel. Level terraces or level grades without outlets are rare and are only suited to very permeable soil conditions that permit a very high rate of water absorption.

Control of Excess Ground Water

Ground water is seldom a problem in upland soils in Tennessee. On bottom lands and stream terrace lands there are large acreages that are imperfectly to poorly drained internally because of too sluggish removal of ground water.

The presence of excess ground water is the result of a naturally high water table, impervious layers in the subsoil or substrata, or to seepage of water from adjacent uplands. The areas affected by excess ground water may be detected by observation of the plant population and the soil characteristics. The plant population will consist of water loving vegetation, depending upon the degree of water saturation and the period of time since the land was disturbed by cultivation. Such grasses as the sedges and larger plants like willows and cattails are common to poorly drained lands. Crops grown on such lands are stunted and often yellow or streaked in color.

Subsoil color and concretions or "buckshot" are good indicators of relative drainage in soils. Mottled gray and yellow color indicates periodic water logging; gray color indicates frequent water logging; yellow indicates moderate drainage and red usually indicates well drained conditions.

Some of the imperfectly and poorly drained soils of Tennessee include Olivier, Calhoun, Falaya, Waverly, Calloway, and Henry soils of West Tennessee; the Taft, Paden, Robertsville, Guthrie, Lindside, Lobelville, Lee, and Melvin soils of Middle Tennessee; and the Robertsville, Lindside, Melvin, Monongahela, Tyler, Purdy, Philo, Atkins, Hamblen, and Prader soils of East Tennessee Valley.

In their natural state of drainage these soils are limited to crops that are compatible with the prevailing moisture conditions. On many of these soils the condition may be corrected by drainage, thus increasing the range of crop adaptability.

Drainage

Drainage may be defined as the rapid removal of excess water. This includes the removal of surface water as well as ground water. The primary purpose of drainage is to remove the excess water in order to allow the use of land for crops of higher economic importance.

Drainage lowers the water table, which encourages root penetration. The deeper root penetration enlarges the feeding area of the plant for both moisture and for plant nutrients. Drainage improves soil tilth and enables earlier cultivation without puddling and clodding. Deeper root penetration also improves tilth by adding organic matter. Winter killing and heaving is reduced by drainage. Water expands markedly when it is frozen, and pushes the young plants and plant roots out of the soil (11). Heaving is serious with small grains, young clover and grass plants. Soil warms up more rapidly following drainage, which encourages earlier tillage and earlier, more rapid activity of the soil microorganisms. The activity of the soil microorganisms is also related to the increased air circulation and penetration brought about by lowering the water table as the result of drainage.

Drainage also increases the percolation rate of water which may result in the removal of plant nutrients by leaching (10). However, the increased vegetative growth which should result from drainage will increase the transpiration and, to that extent, reduce the leaching losses. The increased value of the crop should be sufficient to enable replacement of unavoidable nutrient leaching losses.

Drainage methods available and probably most practical under Tennessee conditions are: open ditches, closed ditches or "blind ditches", and tile drainage. All three of these systems are in use in the state, with more or less success.

Open ditches are applicable when large volumes of water are to be handled, for tile or "blind ditch" outlets, to divert water run-off from adjacent uplands, and in areas where due to shallow outlets and clay pans, tile drainage is not suited. Plowing in small lands, leaving a bedding effect, is also applicable in certain conditions. Ditches are more applicable to large areas. On small areas they are inconvenient, difficult to cross, remove a portion of the land from use, and they are expensive to maintain (41).

Closed ditches or "blind ditches" are ditches in which logs, gravel or stones have been laid and then covered over. These are fairly satisfactory and cost less than tile drainage but they do not remove the excess water as quickly as tile. They do not remove any land from tillage use and they also do not have the maintenance problem of the open ditch.

Clay or concrete tile may be laid in a ditch of uniform depth and grade and then covered. The tile is laid end to end and the water seeps into the tile at the joints and is carried away through the tile. It is only the free or gravitational water that is removed. The efficiency of tile drainage depends upon the nature of the soil and the spacing of the tile lines. Tile lines should be more closely spaced on slowly permeable soils, usually of high clay content. Permeable soils allow wider spacing of tile lines and drain quicker.

Outlets for tile should be deep enough to permit removal of the water and prevent backing up or silting of the tile.

Any form of tile drainage is expensive, and before it is recommended information should be available to indicate that economic returns would be sufficient to warrant the expenditure of capital, labor, and upkeep for the tiling system. Often, the utilization of plants adapted to the less well drained conditions will make consistently higher returns over a period of years than could be expected even after tiling.

Irrigation

Even though the total rainfall in Tennessee is above 45 inches per year there is a need during certain years for irrigation for some crops (42). This is due to the fact that the rainfall is not evenly distributed throughout the entire growing season. Through demonstrations on practical farms the Agricultural Extension Service in cooperation with the Tennessee Valley Authority have shown increased yields of some truck crops as well as forage crops and pasture. In addition there is research now in progress to determine the value of irrigation on truck crops and permanent pastures. Observations so far indicate that the value of irrigation varies with the season according to the amount of rainfall. Irrigation possibilities are limited in Tennessee because of inadequate supplies of water during seasons that irrigation would be most needed (8)(9).

Continued irrigation may have adverse effects upon the soil in row crops as it tends to break down the surface aggregation leading to crust formation (3). The water added is thereby rendered partially ineffective for crop production and reduces soil aeration. Therefore, continued use on the same land may ultimately lead to gradually reduced yields. The addition of organic matter at regular intervals and the use of a sod crop rotation may prevent this effect.

CHAPTER V

ROTATIONS

Crop rotation may be defined as the growing of different crops in recurring succession on the same land, in distinction from a one crop system or a haphazard change of crops without definite plan (11).

A good crop rotation utilizes crops that are adapted to the farm and farming system. The determination of the crop rotation to be used on a farm involves consideration of many factors. Basic to the choice of a rotation is the farmer's desire to get the most out of his farm for the effort he puts into it. The fertility of the soil, its tilth, drainage, reaction, slope, length of growing season, rainfall, weeds, plant diseases, and insect pests determine certain limitations as to the kinds and proportions of crops to be grown. Within these limits, the relative prices of the products that can be produced, the labor distribution throughout the season, the prices of materials and labor used in production, and the number of each class of livestock to be fed determine more definitely the acreages to be devoted to the various crops (41).

Adaptation to soil types is generally recognized as an important factor in determining what crops will be grown. Level lands lend themselves readily to a wide choice of rotations, but as slope, erosion or stoniness, alone or in combination, increase the range of adapted crops and rotations narrows.

In developing rotations that will improve yields attention must be given to (1) maintenance of soil fertility, (2) plant disease and insect control, and (3) weed control.

Different plants have different climatic adaptations. Cotton is a plant adjusted to a long growing season and to relative high temperatures, as compared to a crop such as sugar beets, which is adapted to shorter growing seasons and to generally lower temperatures. The climatic factor, then, determines the adaptability to the areas in general.

Soils vary in their physical make-up from one area to another. These variations may affect the rate of nutrient availability, the availability of moisture throughout the year, as well as the relative ease of root penetration. These differences in the soil affect the type of crops that are or may be suitable to the particular soils. In other words, the crop and the soil should be matched together as nearly as possible to give the best land use and yields. Examples of such matching include the use of white clover, a shallow rooted crop on poorly drained soils; the production of small grains or sorghums instead of corn on the hardpan soils; and the production of alfalfa on the well drained soils. The soil should have the ability to support the plant naturally or with the addition of suitable amendments.

The cost of production, harvesting and marketing of a crop, together with the availability of suitable markets, are important factors in the selection of crops in rotation. These costs when combined may easily remove the profit if a majority of the factors are unfavorable.

The rotation should contribute towards:

A Uniform Acreage of Each Crop Every Year (11). The needs of feed and cash income for every farm varies little each year; as a result the acreages of grain crops, hay crops, pastures and livestock numbers also remain fairly uniform. To accomplish this uniformity of crop acreage it is desirable, though not necessary, to have fields of uniform size. A uniform acreage of each crop if properly selected will aid in distributing labor loads throughout the year. Crops that compete for labor at the same period should be selected with care and the acreage limited to the availability of labor at that particular season of the year.

Weed Control. A rotation with a row crop at selected periods in the rotation contributes materially to weed control. Certain weeds compatible with small grains and sod crops are destroyed during seedbed preparation and cultivation of the row crop. Small grains and grasses if not grazed too closely act as smother crops and in this manner also aid to control weeds. Close grazing will also destroy many weeds, though it is doubtful if this benefit will overcome the harmful effects of trampling and erosion losses.

Control of Insects and Diseases. Rotation of crops is an effective aid in controlling certain wilts, blights and bacterial diseases of plants. If non-susceptible crops are grown on the land for periods of two to five years the danger of such diseases is minimized. To a limited extent a rotation also aids in control of insects by the burial of plant residues in plowing as well as the growing of crops in the rotations that are not subject to such insect damage. Indirectly the stimulated growth resulting from the use of the right rotation will enable the plant to overcome some of the insect damage.

Efficient Use of Subsoil Nutrients. Depth of root penetration varies with different crops and with the physical nature of the soil on which they are grown. As each crop draws its nutrients from its root zone there is a greater tendency ultimately to exhaust the available supply of nutrients if the crops all have rooting systems of about the same depth. Therefore, it is desirable to utilize crops in the rotation with rooting habits which are both deep and shallow. Alternating deep and shallow rooted crops may produce yields larger than when either are grown alone or in succession.

Maintenance of Organic Matter. Row crops have a tendency to reduce the organic matter content of the soil. On the other hand, sod crops of legumes and grasses do not reduce the organic matter so rapidly, but increase or maintain organic matter levels, depending upon the final use of the crop. A rotation of crops that provides for small grain, clover and grasses following intertilled crops such as corn or potatoes aids greatly in maintaining the supply of organic matter in the soil in contrast to growing clean cultivated crops for several years in succession.

Improved Tilth. A succession of clean tilled crops tends toward a poor physical condition because of loss of organic matter. Percolation of water and air and nitrification processes are slowed down and there is more difficulty in obtaining stands and in cultivation. Small grain, legume and grass roots permeate the surface soil, leave organic matter, and tend to aid in granulation of the soil, thereby improving the physical condition or tilth. The plant cover furnished by sods in the rotation intercepts the impact of rain and may hold at least temporarily from one-fourth to one-half of a light rain.

Increased Crop Yields. The cumulative effects of the previously discussed advantages of a rotation usually result in increased crop yields as research data of many experiment stations show. Crop rotation alone cannot maintain the productivity of the soil. Where a supply of farm manure is available and properly utilized, particularly along with commercial fertilizers, the maintenance of a high fertility level is comparatively easy. Where manures are not available and crops are continually removed, green manures should be used to replenish the organic matter. Table XV gives results of 50 years work on Sanborn Field at the Missouri Agricultural Experiment Station (34).

TABLE XV

AVERAGE YIELDS DURING 50 YEARS OF CROPS IN VARIOUS ROTATIONS AND CONTINUOUS CROPPING SYSTEMS

	CORN		OATS		WHEAT		CLOVER		TIMOTHY	
Cropping System	No treatment	Manure	No treatment	Manure	No treatment	Manure	No treatment	Manure	No treatment	Manure
	bus.	bus.	bus.	bus.	bus.	bus.	lbs.	lbs.	lbs.	lbs.
6-Year rotation	37.9	50.8	29.7	31.9	18.5	28.2	2059	4464	2500	4525
4-Year rotation	36.6*	45.0	26.8*	37.2	21.6*	21.5	2216*	4000	—	---
3-Year rotation	31.7	46.9	---	---	13.8	25.1	1656	4446	---	---
Continuous corn	18.5	33.1	---	---	---	---	---	---	---	---
Continuous oats	---	---	20.1	33.0	---	---	---	---	---	---
Continuous wheat	---	---	---	---	10.3	18.8	---	---	---	---
Continuous timothy	—	---	---	---	---	---	---	---	2530†	5097

* Has been contaminated by lime dust from street.

† A poor quality of timothy because of much weeds.

Continuous corn and no manure gave a yield of 18 bushels over the 50-year period as compared with a yield of 38 bushels for corn in a rotation. With manure the yield for corn alone is 33 bushels and in rotation is 51 bushels. These data indicate that over the 50-year period the value of the rotation is 20 bushels per acre with no manure and 18 bushels per acre with manures. In addition to reduced erosion losses, the increase or maintenance of organic matter levels, the improved tilth conditions and the improved control of disease and insects, all are values or benefits but are difficult to evaluate accurately.

Due to the wide variation in soils and climate there are possibilities for many different rotations to be developed under Tennessee conditions. Most all of the crops of the north, south, and mid-west may be grown here and a wide variety of farming systems including livestock, cotton, tobacco, small grains, corn, truck crops and general farming are practicable.

An evaluation of the physical condition of the soil involves the soil depth, soil water holding capacity, the prevailing slope, the amount of stoniness, the extent of erosion, the erodibility of the soil and its relative permeability to water. When these factors along with climatic conditions and fertility are properly considered, then the selection of crops and their sequence as well as the length of rotation may be selected.

The length of rotation or period of years between row crops varies with the number of favorable or unfavorable soil properties. Level, fertile, well drained soils may be used in a short rotation, whereas a level, imperfectly drained soil of low fertility may require a longer rotation. As the levels of fertility become lower, or the slopes increase, or erosion hazards increase, the need for long rotations increases.

A three-year rotation of wide popularity in the state is first year a row crop followed by small grain, with clover and grass the second and third years. This rotation is sometimes lengthened by allowing the clover and grass to remain for three to five years before returning to a row crop.

This rotation fulfills most requirements: it contains legumes and grasses, deep-rooted and shallow-rooted crops, as well as pasture grass and a cultivated crop; it also provides good alternation of crops and a vegetative cover the major portion of the time.

CHAPTER VI

TILLAGE

Tillage operations are performed for four primary purposes. First, to prepare seedbeds for subsequent planting. Second, to eliminate weeds that may compete with the crop for moisture and plant nutrients. Third, to control tilth, or improve soil physical condition which will aid in the improvement of water, air, temperature, and plant nutrient relationships. Fourth, to incorporate organic matter and fertilizers, which is sometimes done as a part of seedbed preparation. Insect and disease control may be also indirectly obtained through incorporation of organic matter.

Erosion and tillage are closely related. However, tillage is not the only factor in the acceleration of erosion. Overgrazing may be just as important a factor in producing excessive erosion as tillage. Tillage performed carelessly may increase susceptibility to erosion; tillage on the contour gives low rates of water runoff and thus promotes water absorption. "Trashy tillage", that is tillage methods that leave crop residues on the surface soil, reduces soil and water losses; clean, level tillage may increase these losses.

Seedbed preparation is an important operation because an inadequate or faulty seedbed cannot be corrected in later cultivation. Inadequate seedbed preparation may reduce the yield of the crop.

A good seedbed should be smooth and free of residues to facilitate planting operations. The seedbed should be of fine, mellow, compact structure, but loose enough to permit oxygen entry to the seed, yet compact enough to give good seed contact and permit capillary water movement.

Plowing is the fundamental operation for a seedbed. Disking to break clods, and to some extent to compact the soil, usually follows plowing.

The time of plowing depends upon seasonal conditions. In Tennessee fall plowing is not recommended as a preparation for spring seeding due to the mild temperatures which prevail through most of the winter. The soil is seldom frozen and then for only short periods. Thus leaching is more pronounced and continues with little check. The winter rains have a compacting action on the soil after it is plowed, often leaving it so firmly compacted that plowing is again required in the spring. If frost action were more prevalent some of the compaction might be prevented. Under these conditions it is preferable to plow in the spring for spring planted crops and in late summer or early fall for fall sown small grains and clovers. On heavy clay soils fall plowing for spring crops may aid in seedbed preparation by the slaking action of the weather on the large clods left after plowing. This action may aid in finishing the seedbed quickly for the spring planted crops.

Seedbed preparation should begin early enough before planting the crop to permit initial decomposition of residues, to allow firming the seedbed and to avoid undue loss of moisture by the transpiration of cover crops.

The physical character of the soil influences the interval needed between plowing and planting. Sandy soils settle and compact quickly, hence often one or two weeks prior to planting is sufficient interval for plowing before planting. On loams such as silt loams the interval should be greater as the physical process of compaction or settling is slower. On clays sometimes a month or longer is needed as the soil is apt to require more disking to compact the seedbed.

Moisture content of soils affect the time of plowing. Sandy soils are suitable for plowing over a wide range of moisture. They can possibly be plowed best when wet. For loams such as silt loams the soil should be neither too wet nor too dry but moist. Clays should be moist for best pulverization by the plow. If too wet or too dry, clay soil will break into clods which will sometimes require several months for granulation. The physical character of the subsoil influences the amount of moisture in the soil. Claypans, hardpans or plow soles restrict the water movement in the soil, which results in the surface soil remaining wet for longer periods. These surface soils become quite dry rather quickly in summer.

Plowing is usually at depths of from 4 to 10 inches. As a general rule plowing should be performed at a minimum depth to accomplish the purposes, such as to cover residues, and to furnish a proper medium for seed germination and root development. The expense of plowing increases with depth as more power is required to plow deep than shallow. Available data indicate that little is to be gained from deep plowing. However, the depth of plowing will depend upon the kind of crop, season of year, the type of soil and unusual conditions such as plow soles and subsoiling.

Director Mooers in Bulletin 191 of the Agricultural Experiment Station has summarized experiments on Cumberland loam in East Tennessee, Baxter cherty silt loam of the Highland Rim, Olivier silt loam and Lintonia silt loam in West Tennessee on various depths of plowing as quoted below:-

Corn

1. Depth of plowing
   a. Six-inch plowing gave nearly maximum yields in all trials.
   b. Neither subsoiling nor extra-deep disk plowing proved profitable.

2. Cultivation of the growing crops:
   a. A decided difference was found between the more granular and gravelly types of soil that characterize East and Middle Tennessee and a typical silt loam of West Tennessee. The latter has an appreciably higher silt and lower clay content. On the more granular soils, no cultivation, with weed growth controlled by scraping or very shallow cutting with a hoe, gave unsurpassed yields, but on the high silt loam soil no cultivation resulted in decidedly decreased yields.
   b. On the more granular soil types, cultivation was valuable only for weed control. Therefore, cultivation with the sole object of maintaining a soil mulch is not justified.
   c. If no cultivation is excepted, the yields on all soils were practically uninfluenced by the method of cultivation.

Cotton

1. Depth of plowing and bedding, on poor land and on rich land:
   a. Under level culture, 3-inch plowing resulted in as large crops as 6-inch plowing in both series.
   b. Where land was bedded, but not flat-broken, the yields were favorable to 6-inch bedding rather than 3-inch, in both series.

2. Bedding with and without previous plowing:
   a. In the poor-land series, plowing preparatory to bedding proved distinctly unprofitable.
   b. In the rich-land series, the preparatory plowing proved profitable.

3. Early versus late soil preparation:
   a. Early plowing and early bedding gave appreciably better yields both at the 3-inch and the 6-inch depth of preparation.
   b. Under level planting, early plowing was notably superior.

4. No cultivation (except weeds scraped off) compared with good cultivation, on poor land and on rich land:
   a. In the poor land series, good cultivation resulted in yields nearly 30 percent larger, on the average, than were obtained under no cultivation.
   b. In the rich land series the average yields from good cultivation and no cultivation were practically identical. The difference in outcome between the poor-land and the rich-land series is attributed to the more granular condition of the rich soil.

Farmers usually plow too much because they do not practice a good soil building rotation, and grow too many shallow-rooted annual crops on the land each year. Also, farmers plow for some crops when a shallow surface seedbed preparation is all that is needed.

Two good rules to follow are: (1) Consider the type of crop that is on the land to be or not to be plowed. Sods and deep rooted legumes such as alfalfa and sweet clover should be plowed to give maximum results. (2) Consider the kind of soil you have. Clay soils need plowing to obtain a good seedbed more often than do sandy soils. Plowing imparts more air and better water-holding properties to the soil.

The value of subsoiling is somewhat questionable on many soils. Some advantages of subsoiling include increasing the infiltration capacity of the soil at least temporarily, breaking up plow soles and increased root penetration. Infiltration may be increased on soils like Baxter, Fullerton, Decatur, Dewey, Talbott, Maury, Memphis and Lexington for varying periods of time. Subsoiling is of very doubtful value on soils such as Henry, Guthrie, Robertsville, Lickdale, and Tyler as their subsoils are plastic clays and would likely "run" together quickly.

Operations subsequent to plowing in seedbed preparation include disking, cultipacking and planting. Their purpose is to level, pulverize and compact the seedbed in order to obtain a mellow, firm, but not too compact a seedbed. The cultipacker or roller is very practical for the purpose of firming the seedbed. Planting operations are performed with one or more row drills and broadcast drills such as grain drills. Most of these compact the soil surface simultaneously with the planting.

One of the primary purposes of tillage is weed control. Weed control is involved in both seedbed preparation as well as during cultivation of the growing crop. Weeds compete with the crop for water, plant nutrients, light and space. Weed growth should be encouraged in Tennessee only under conditions where the land would otherwise be bare and subject to excessive losses by leaching and erosion. Under such conditions weeds would be a "cover crop".

Weeds should be destroyed early before they have injured the crop and while they may be destroyed by shallow cultivation. If done early, cultivation will not injure the plants by cutting the roots. To avoid crop injury cultivation should be shallow except the first cultivation which may be deep.

The frequency of cultivation will depend upon weed growth. If weeds are killed by cultivation while they are small, extra cultivation is not needed until a new growth of weeds develop. Even then the crop should not be injured by tillage just to kill a few weeds. The rate at which a crop grows and its nature of growth often determine the frequency of cultivation. A good stand of corn growing fast will require less cultivation and will suffer less competition from weeds than a poor stand of stunted, slow growing corn.

Non-row crops such as permanent pastures and alfalfa are sometimes cultivated to control weeds and to cover top-dressings of fertilizer. This is usually done in early spring to kill weeds and often in early fall to cover fertilizers.

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