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The Composition and Properties of Some Texas Soils

By

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THE COMPOSITION AND PROPERTIES OF SOME TEXAS SOILS.

G. S. Fraps, Chemist.

In the last several years, a number of analyses of Texas soils have been made by the Chemical Section of the Texas Experiment Station. The samples have been collected in a systematic way, and represent definite areas and types of soils in the State. Most of the samples represent the types of soils in areas surveyed by the Bureau of Soils of the United States Department of Agriculture, the samples being furnished by that Bureau to this Station.

In addition to the chemical analyses, tests for deficiencies were made by pot experiments on some of the soils, and some were also treated with solvents to determine the active plant food present. This work, it is believed, shows, to a large extent, the properties and deficiencies of the soils studied. This work, while of particular interest to the counties represented, is also of general interest, since many of the soils represented are widely distributed in the State.

What Constitutes Soil Fertility.

In order for a soil to be fertile, a number of conditions favorable to the life of the plant must be fulfilled. The largest crop is secured when each of these conditions has reached its most favorable (or optimum) position, and the farther any one or more of them departs from the optimum, the smaller is the resulting crop. The size of the crop depends upon the condition which is farthest from the optimum.

We will discuss, briefly, these conditions. They are, temperature, water, space, physical condition of soil, and plant food.

Temperature. A favorable temperature is necessary for plant growth, but as temperature is little subject to control, except on a limited scale, we will not discuss it here.

Water. Water is a very important factor in crop production. In order to produce the largest crop, the soil must possess a certain amount of water, and the size of the crop is lessened if the amount of water decreases or increases beyond this point; that is, if the soil becomes too wet or too dry. The amount of water most favorable to the crop depends upon the nature of the soil and the kind of crop. A clay soil requires more water than a sandy soil, but at the same time the clay soil has a greater power of holding water. The deeper the roots can penetrate into the soil, the greater is the amount of water placed at their disposal.

The quantity of water in the soil at any given time depends upon the rainfall, the location and character of the soil, and the treatment it has received. Cultivation after a rain, by breaking up the crust, and forming a dust mulch, prevents loss of water by evaporation.

A soil that is naturally wet is not suitable for most cultivated crops. Some soils are naturally too porous and open to retain sufficient water for the maximum production of a crop. In such event, no matter how much fertilizer is applied, the production cannot be forced beyond a yield depending upon the amount of water at the disposal of the plant. It must not be forgotten, then, that water is an essential element in soil fertility, and an unfavorable condition as regards water will reduce the size of the crop.

Space. The largest individual plant is secured when the plant has the optimum amount of space at its disposal, for the extension of both foliage and roots; by increasing the number of plants per acre, the size of the individual plant is decreased, but the crop is increased up to a certain point, on account of the increase of the number of plants. Beyond this point there is decrease, on account of over-crowding.

The space afforded to the roots depends upon the distance between the plant and the depth of the soil. Not only is the amount of space increased as the soil is made deeper, but the water and plant food presented to the roots increase with the bulk of soil which they can penetrate. For this reason, the depth of the soil is an important factor in its fertility. The depth of the soil may be increased by proper methods.

Physical Condition. The physical condition of the soil determines the amount of water which it absorbs and holds, and also the penetration of air into it. Air is necessary both for roots of plants and for changes in the soil essential to its productiveness.

The physical condition of a soil depends upon its physical composition, its chemical composition, and the treatment to which it has been subjected.

Plant Food. The plant takes up a number of things from the soil through its roots, some of which are essential to its proper growth and development. If these substances are withheld, the plant ceases to grow. The essential substances taken from the soil are as follows:

Phosphoric Acid,
Nitrogen,
Potash,
Lime,
Magnesia,
Sulphur,
Iron,
Chlorine,

A large number of experiments have shown that practically all soils contain an abundance of all these substances for the production of large crops, with the exception of the following: phosphoric acid, potash, nitrogen, and lime. That is to say, soils may not contain sufficient phosphoric acid, potash, nitrogen or lime; if the element lacking is supplied in a suitable form, the crop will be increased. Lime, however, is needed by the soil rather than by the plant.

The object of **fertilizers** is to supply phosphoric acid, nitrogen or potash, or mixtures of these, in such forms that plants can take them up rapidly.

Soils may contain sufficient plant food to produce a number of crops, but because the crop is removed and sold, taking the plant food with it, the store in the soil is gradually depleted.

Active Plant Food. A soil to be fertile must contain not only sufficient plant food, but the plant food must be in such forms that the plant can take it up. We apply the term "active" to the plant food which can be taken up by the plant.

A soil which has recently been placed in cultivation usually contains enough "active" plant food to produce a good crop. A poor soil will decrease in productiveness in a few years, while a good soil will continue to yield profitably for many years. In the first case, the supply of active plant food is not sufficient for a good crop, while in the second case, the active plant food continues to be present in necessary quantity. The poor soil may even contain considerable amounts of plant food, but is unproductive on account of absence of one or more forms of "active" plant food.

Causes of Small Crops Due to the Soil.

A productive soil presents favorably all the conditions for plant growth. An unproductive soil is deficient in some respect or other, or presents some injurious condition.

Recognition of the presence and nature of the causes of a small crop may enable us to counteract them. Deficiencies or injurious conditions are due to **physical** and to **chemical** causes.

Physical Causes. A soil may be limited in depth by water, hard pan, rock, or an impervious subsoil; it may be too porous or too stiff, too wet or too dry, too cold or too shallow; it may be unfavorably located. These conditions all affect the size of the crop.

Soils limited in depth by water, or which are too wet, are relieved by suitable drainage. Cold soils are usually wet, and become warmer when drained. Shallow soils may be made deeper by gradually ploughing a little deeper each year, or they may often be improved by subsoil ploughing.

Porous and stiff soils are benefitted by organic matter, such as manure or green crops, which makes the porous soils less porous and the stiff soils less stiff. Lime may improve clay soils by making them less stiff and more easily worked.

By proper methods of cultivation, water can under some conditions be stored and conserved in the soil, so as to render possible the production of crops without irrigation in some regions of little rain-fall. We cannot go into a detailed discussion of these physical causes of low crop yields, and the methods for their prevention.

Chemical Causes of Deficiencies. The chief chemical causes of deficient crops which may exist in a soil, are as follows:

Acidity
Alkali
Deficiency of active plant food.
Deficiency in active lime.
Deficiency in active organic mater.

Acid soils contain free organic or inorganic acids,which give them an acid reaction. They may be recognized by the fact that they turn blue litmus paper red, Most crops are injured by acidity, although, there are some, such as cranberries, which do best in an acid soil. Acidity is corrected by application of lime to the soil. The amount of lime needed depends upon the extent of the acidity.

Alkali soils contain soluble salts, such as sulphate of soda, chloride of soda, and carbonate of soda. The last named is the most injurious; when it is present, the soil has a dark color and is said to contain **black alkali.** If there is not too much alkali present, some crops may be grown upon the land;

but if there is too much, it must be removed if the land is to become of any value.

Deficiency of active plant food. A soil must contain sufficient active plant food for the production of the crop. It does not matter how much total plant food may be present, if there is a deficiency of active phosphoric acid, potash, or nitrogen, the crop suffers.

The amount of active plant food in the soil depends upon the nature of the soil, and the conditions surrounding it. Often the amount of active plant food is proportional to the total plant food, but this is not always the case. The presence of sufficient moisture, and vegetable matter, appear to aid in the maintenance of a supply of active plant food in the soil. A "run down" soil may often be brought up by increasing the activity of the agencies which make inactive plant food active.

Deficiency in Active Lime. When a soil receives benefit from lime it is usually considered to be an acid soil, but this is not always the case. Active lime has a beneficial effect upon the soil in several ways. It aids in nitrification, or the production of nitrates (active nitrogen) from organic bodies containing nitrogen. It appears to render phosphoric acid active. Soils which contain an abundance of lime and a low percentage of phosphoric acid retain their fertility longer than those which are deficient in lime with larger amounts of phosphoric acid. Lime also improves the physical properties of clay soils, making them more easily tilled, and less sticky. It aids in maintaining a supply of active potash in the soil.

Deficiency in Organic Matter. Soils which are subjected to such methods of cultivation that the organic matter in them diminishes, eventually decrease in fertility. The organic matter contains a store of nitrogen, which is exhausted as the organic matter becomes less. The organic matter also presents favorable conditions for the growth of microscopic organisms, (bacteria) which aid in maintaining a supply of active plant food in the soil. The organic matter makes the soil more retentive of moisture, and has a favorable effect upon the physical character of the soil, rendering clay soils less stiff, and sandy soils less porcus, and more retentive of moisture.For these reasons, it is important to maintain a favorable amount of organic matter in the soil.

Maintaining Soil Fertility.

If a soil is already fertile, in order to maintain its fertility, the favorable conditions must be retained.

First, the organic matter present should not be allowed to fall too low, but the losses which take place during cultivation should be restored by means of barn yard manure, or by ploughing under green crops.

Second, a sufficient supply of active lime must be maintained. Lime is lost in the crop which is carried away, and in the water which passes through the soil. If a sufficient quantity of active lime is not maintained, the soil will produce a smaller quantity of active plant food each year and will decrease in fertility, and it may also become acid. Some crops require more active lime than others.

Third, a sufficient quantity of active phosphoric acid, potash, and nitrogen must be maintained in the soil. There are soils in which this can be done for a time by thorough cultivation, the use of green crops, and the prevention of losses of active plant food as far as possible; but eventually the fertility of the soil cannot be maintained without the use of manures or fertilizers.

Active plant food is lost from the soil in two ways: First, it is taken up by the crop, and removed with it; and, second, it is lost by leaching. A portion of the plant food remains in the straw, leaves and other by-products of the crop; and if these are saved and returned to the soil, the loss through the removal of the crop, is correspondingly decreased.

The losses of plant food per acre, due to crops, vary according to the size of crop, etc., but approximate values for cultivated crops are given in the following table:

Table No. 1.—Plant Food Removed by Crop, in Pounds Per Acre.

	Phosphoric Acid	Nitrogen	Potash
Corn, 40 bu. corn and cob	19	38	13
Wheat, 25 bu.	13	29	8
Oats, 40 bu.	10	25	7
Cotton, 250 lbs. lint	0.1	0.8	0.7
Potatoes, Irish, 100 bu.	10	20	36
Potatoes, sweet, 200 bu.	20	28	72
Alfalfa, 4 tons	50	183*	143
Sorghum, 3 tons	29	84	134
Sugar Cane, 20 tons	15	153	44
Onions, 3,000 lbs	37	72	72
Rice, (1,900 lbs.)	12	23	5

* A portion of this nitrogen comes from the air.

In addition, the following amounts of plant food are lost if the by-products of the crop are not returned to the soil.

Table 2—Plant Food in By-Products of Crops in Pounds per Acre.

	Phosphoric acid	Nitrogen	Potash
Cotton (seed, 500 lbs.)	7 lbs.	16 lbs.	8 lbs
Cotton (stalk and leaves)	12 "	32 "	23 "
Corn (stalk and leaves)	6 "	22 "	29 "
Wheat (straw)	5 "	13 "	14 "
Oats (straw)	4 "	10 "	21 "
Rice (2250 lbs. straw)	3 "	14 "	37 "

If the by-products are burned, and the ashes returned to the soil, only the nitrogen is lost, but nitrogen is the most expensive kind of plant food.

Plant food is also lost from the soil in the water which passes through it. Phosphoric acid is lost in this way to a small extent, potash somewhat more, but the greatest loss is nitrogen, which is washed from the soil in the form of nitrates and ammonia. Often more nitrogen is lost by washing from the soil than is taken up by the crop.

It is obvious that plant food cannot be continuously lost from the soil without a decrease in fertility sooner or later. All, or a portion of the loss, must be restored in order to maintain the soil in a fertile condition.

Plant Food can be Restored to the Soil in Several Ways:

(1) **By manure.** Manure contains a portion of the plant food which is fed to the animals. There is always some loss in its collection and preservation, and unless a quantity of feeding stuffs are purchased, manure alone cannot maintain the fertility of the soil. Manure is, however, of benefit to the soil by virtue of the organic matter which it contains, and it should be preserved and utilized as thoroughly as possible.

(2) **By leguminous crops.** Leguminous crops have the power of taking up nitrogen from the air, and fixing it so that it is of value to other plants. If, then, leguminous crops such as cowpeas, alfalfa, clover, peanuts, beans, etc., are grown they secure a portion of their nitrogen from the air, and add to the fertility of the soil, if ploughed under. The roots and stubble also add to the fertility of the soil; but, perhaps, the most effective way of using leguminous crops, is to feed them, save the manure carefully, and use it on the soil.

Every farmer should grow leguminous crops as extensively as possible, for his own use in feeding, or for sale, or for ploughing under. The importance of these crops will become greater and greater as the nitrogen in the soil decreases. Nitrogen is the most expensive kind of fertilizer, and, so far as possible, it should be secured from the air and not by purchase in feeding stuffs or fertilizers.

Leguminous crops do not add to the store of phosphoric acid or potash in the soil, and may indeed require these fertilizers to effect their best growth. However, the organic residues which they leave may aid in rendering inactive potash or phosphoric acid active.

(3) **By Fertilizers.** Fertilizers may contain phosphoric acid, nitrogen, and potash, in active forms, and are used to supplement the active plant food of the soil. (For a discussion of fertilizers, see Bulletin 96, of this Station.)

Increasing Soil Fertility.

Before attempting to increase the productiveness of the soil, it is advisable to ascertain the cause of its low crop value, if possible, and then take the proper measures to overcome these causes.

Low productiveness may be due to a number of causes, such as we have already pointed out under the discussion of soil deficiencies. It may be due to the climate or location of the soil. The soil may be too shallow, too porous, too wet, too dry; it may be acid in character, or contain alkali; or it may be deficient in plant food. The general methods of increasing soil fertility are as follows:

Acid Soils must be treated with lime to correct the acidity, unless crops which are not injured by acidity are to be grown (such as cranberries).

Organic Matter, if present in small quantity, should be increased by the use of manure or by ploughing under green crops. In the latter event, it may be necessary to use a fertilizer containing phosphoric acid and potash to secure a good growth. The crop selected should be some leguminous crop, which will not only add organic matter to the soil, but will also take nitrogen from the air and thus increase the store of this valuable plant food in the soil.

The organic matter improves the physical character of the soil, and increases the activity of the agencies which change inactive plant food to active.

By proper use of green crops and manure, many poor and unproductive soils have been increased greatly in fertility. The green crops are often planted when the crop is laid by; for example, cowpeas are often planted in this way between the rows of corn.

Active Plant Food should be increased, first, from the stores in the soil by the use of green crops and manures, and second, by the use of commercial fertilizers. Except for truck crops, and other crops of high value per acre, the farmer should endeavor to secure all the nitrogen that he needs from the air, and he should purchase only phosphoric acid and potash in the form of commercial fertilizers.

The best fertilizers to be used depends upon the character of the soil, and the crop to be grown.

Chemical Analysis of Soils.

The chemical analysis of a soil must be taken in connection with a knowledge of its location, depth, drainage conditions, permeability to water and air, and, if possible, its productiveness. Without consideration of the other factors which influence the fertility of the soil, the chemical composition may not lead to satisfactory conclusions. We must also remember that the same general type of soil varies somewhat in composition, physical properties, and productiveness within a given area, and also that different methods of farming may cause considerable differences in soils originally the same.

Chemical examination of a soil may be made in several ways:

(1) By complete decomposition of the soil. In this process, a determination of the total amount of each ingredient is made. The writer is of the opinion that the results of such analyses are not as valuable as those secured by the method which follows.

(2) By partial decomposition of the soil with strong acids. This method, using hydrochloric acid of 1.115 sp. gr. is the official method of the Association of Official Agricultural Chemists, and was used in the work described in this bulletin. It is believed that this method gives valuable information as to the wearing qualities of the soil, and also some indications as to the causes of low crop yields, or of decrease in productiveness. As before stated, the chemical analysis must be considered in connection with the location, depth and other properties which affect the fertility of the soil.

(3) By partial decomposition with weak solvents. These methods attempt to indicate the deficiency of the soil at the time of the analysis. These methods are now under study by the Texas Experiment Station, and statements with regard to the results will be made later.

Value of Chemical Analyses.

The interpretation of a chemical analysis unaccompanied by knowledge of the other soil conditions which affect its fertility may be unsatisfactory in a large proportion of cases. A careful interpretation of results with the aid of the knowledge referred to, may sometimes be disappointing, but is more often correct. Analyses of miscellaneous samples of soils is also of less value than systematic studies of definite areas. Analyses of virgin soils, or soils which have not been long under cultivation, or treated with fertilizers, are more likely to yield a satisfactory interpretation than analyses of soils whose properties have been modified by long-continued cultivation, or by applications of fertilizers. It cannot be expected that chemical analysis of soils will always give satisfactory interpretation; there will be exceptions to the rule, but the rule should hold in the majority of cases.

Chemical analysis of soils with strong acids gives us information with regard to the wearing qualities of the soil, under a given system of cropping, and indicates what deficiencies are liable to exist, or to be produced later.

Chemical analysis of a soil with strong acids, together with other information concerning the soil, should aid us in applying the results secured by field experiments in one locality on a given type of soil, to other localities and to other types of soil. It is well known that the results of field experiments with fertilizers are applicable only to the same types of soils under similar conditions and with similar chemical composition, and may, or may not, be applicable to other types of soils. Chemical analysis, and the other information referred to, should aid us in applying knowledge secured by such field experiments and by experience to the same type of soils located in different sections of the state, and even to different types of soil from those under experiment.

Interpretation of Chemical Analyses.

The chemical analyses made with strong acid presented in this bulletin are interpreted by the aid of the standards of Dr. E. W. Hilgard, and we have found that the chemical analysis interpreted in this way is, in general, in accord with the productiveness, and wearing qualities, of the soils as reported by the field agents of the Bureau of Soils. It appears probable that chemical analysis of this kind, on the character of soils which we have studied, is of more permanent value than the estimation of the active plant food at any given time. The latter determination may show the immediate needs of the soil, which may vary from time to time, according to the treatment which the soil receives. The analysis with strong acids appears to show the permanent strength or weakness of the soil, particularly its wearing qualities. The active plant food in a good soil may be increased by appropriate treatment; but in a poor soil, while the increase may be effective for a time, only additions of plant food can give a permanent increase in productiveness. We are therefore inclined to believe that chemical analysis of soils with strong acids is, at least, equally as valuable as the estimation of the active plant food present at any given time. We may eventually secure a method which gives the quantity of active plant food in the soil; that is, the quantity which can be utilized by a given crop. But the active plant food varies according to the conditions to which the soil is subjected; it is possible to increase the active plant food in a good soil, so that it passes from an unproductive to a productive condition, by the use of organic matter, manure and proper cultivation. The active plant food, therefore, is variable and depends upon the treament of the soil, and its composition. The determination of active plant food is, therefore, of more or less temporary value.

The analysis with strong acids shows us the total quantity of plant food which may become available; the active plant food cannot be increased beyond a certain proportion of this quantity. If, therefore, the total quantity of plant food is small, the soil cannot be increased in fertility, to any great extent, without external supplies of active plant food, and if its fertility is increased without this addition, the fertility cannot last long, because the supply of food in the soil will be exhausted. The total plant food changes slowly, the active plant food is subject to larger variations. A soil which contains a good supply of plant food may be increased in crop value when run-down, but if the supply of food is small, this cannot be done. The analysis of the soil by strong acids, therefore, indicates the wearing qualities of a soil, and its capabilities under suitable treatment.

Chemical Analysis With Weak Solvents.

The object of the chemical analysis with weak solvents is to determine the active phosphoric acid and potash in the soil, and thereby ascertain which of these the soil needs immediately, and also the quantity thereof. A number of solvents have been proposed, such as 1 per cent citric acid, N-5 hydrochloric or nitric acids, N-200 hydrochloric acid, and others, the most promising of which appear to be the 1 per cent citric acid and N-5 nitric acid. The subject, however, requires considerably more investigation before we can be able to tell exactly what is the significance of the dissolved material. The matter is further complicated by the fact that plants differ in their need of plant food, and in their power of extracting it from the soil.

This method of analysis is under investigation by the Texas Experiment Station. The work is not completed or ready for publication, but so far as phosphoric acid is concerned, in the different areas of the State examined, the order of the soil fertility as found by pot experiments is the order of the percentages of phosphoric acid dissolved by N-5 nitric acid. Whether this fact will hold in the experiments now under way, remains to be demonstrated, but at present it appears likely that the fifth-normal nitric acid method, or some modification, will give valuable results so far as indicating deficiency of phosphoric acid is concerned.

Pot Experiments.

Pot experiments, if properly conducted, are adapted to show the deficiencies of the soil in phosphoric acid, nitrogen, potash, or lime. In conducting such experiments, it is important that each pot in the series should receive similar treatment, and be under the same conditions.

The plants should be allowed to grow to maturity, if possible, and emphasis should not be placed upon slight differences in the weight of the crop, since duplicate pots may differ to a small extent.

In the pot experiments which we have conducted, pots were used 8 inches in diameter and 8 inches tall, with a side-tube 1 inch in diameter. The side tube connects in the interior of the pot with a semi-circular sheet of zinc, with notches cut in the side. The pots are brought to equal weight with gravel (about 2 lbs.) and filled with the soil, which has been passed though a 2-mm sieve. The pots were maintained at a constant water content, by weighing, and adding water about three times a week. The first series of experiments were carried on in a glass house belonging to the

Horticultural Department. The second series was on trucks covered with wire mosquito netting. We are now using a house covered with canvas.

In order to ascertain the effect of a given food, we compare the crop with all food except this food, with a crop with a complete mixture. These tests have been made on a number of Texas soils, and will be described in their proper places.

The pot tests which we have made give the immediate needs for plant food of the soils which we have examined. Some of these samples were from virgin soils, and some were from land which had been a long time under cultivation. Because of these facts, and because of the fact that the active plant food in a soil depends to some extent upon the treatment which it receives, we cannot be certain that the deficiencies revealed by a test on a single sample of a given type prevail generally for that type in the area given. For the same reason, the pot tests cannot be expected to agree always with the conclusion drawn from the analysis with strong acids, since the active plant food has been reduced in some of the soils, and has not in others.

A general conclusion can however be drawn from our pot experiments. As a general rule, Texas soils respond to fertilization with phosphoric acid first; nitrogen, second; and potash,least and last of all. There are exceptions to this rule, of course, but for most of the soils we have examined, the rule appears to hold.

The U. S. Soil Survey.

The samples of soils analyzed in this work were sent to us by the field agents of the Bureau of Soils of the United States Department of Agriculture, through the kindness of the Chief of the Bureau, Prof. Milton Whitney, to whom our indebtedness is hereby acknowledged.

The soils of a given area are classified into different types by the field agents, according to color, depth, physical character of soil and subsoil, origin and other characteristics. Soils of the similar origin and character. but differing in physical composition, are grouped together in series. Where possible, soils of one area are brought into relation with those of other areas, and similar names are given for similar types.

The different types of soil represented in each area are mapped, and the maps, together with a description of the area and the properties and characteristics of the soils, are published by the Bureau of Soils. These publications have to do entirely with the physical character of the soil, and information collected by the field men. The maps and descriptions of the different areas can be secured by application to your Senator or representative in Congress, or to the Secretary of Agriculture.

General Physical and Chemical Characteristics of Some Soil Types.

The series of soils we have subjected to study and which appear in two or more of the areas here described, are six in number. We will here describe the general characteristics of these soils, and discuss the relation between their chemical composition in different areas. These types do not by any means represent all the kinds of soils found in Texas. Some very fertile soils are not represented.

Norfolk Soils. These are light colored upland sandy soils, with a yellow clay or sandy clay subsoil, usually with good drainage. The most important truck soils of the coastal plain are included in these soils.

Of the areas under study, the Norfolk soils are found in Anderson, Houston, and Bexar counties. They are widely distributed in the Eastern part of the State.

Chemical Characteristics. The Norfolk soils from widely separated areas are strikingly similar in chemical composition. They are characterized by a high content of insoluble material, and a low percentage of phosphoric acid and nitrogen, being generally deficient in these forms of plant food. Lime and potash are also low, but often sufficient. Organic matter is low The average composition of the Norfolk soils is given in Table 3.

These soils should respond to fertilization with phosphate fertilizers, and also nitrogen. In some of them the use of potash and lime would be advisable. Organic material, such as green crops plowed under, and stable manure, have a very beneficial influence upon these soils. These soils are very much benefited by leguminous crops which take nitrogen from the air.

Orangeburg Soils. The Orangeburg soils are gray to brown upland soils, with a red or yellowish clay sandy subsoil. The red color of the subsoil distinguishes the Orangeburg soils from the Norfolk soils. The red soils appear to be more productive and are generally stronger than the corresponding soils of the Norfolk series. The Orangeburg soils are widely distributed, especially in East Texas.

TABLE 3—AVERAGE PERCENTAGE COMPOSITION OF SOME TEXAS SOIL SERIES.

	Norfolk series	Orangeburg series	Lufkin series	Susquehanna series	Houston series	Yazoo series
Phosphoric Acid	.02	.05	.02	.03	.06	.11
Nitrogen	.05	.06	.05	.07	.14	.08
Potash	.12	.37	.11	.22	.34	.39
Lime	.08	.40	.39	.31	...	6.87
Insoluble and Soluble Silica	96.	90.	94.	88.	...	62.

Chemical Characteristics. The Orangeburg soils are somewhat more variable in composition than the Norfolk soils, particularly in insoluble matter, but the resemblance between the soils of different areas is still striking, especially if similar grades are compared. The Orangeburg soils are better supplied with plant food than the Norfolk soils, particularly phosphoric acid, and this is in accordance with the fact above noted that Orangeburg soils are stronger and more durable than Norfolk soils.The content of phosphoric acid and nitrogen in these soils is, however, very low, and many of them are deficient in these forms of plant food, or will shortly become so. In respect to lime and potash, the supply is somewhat better. These soils also contain a low content of organic matter. Table 3 gives the average composition of the Orangeburg soils.

Lufkin soils. The Lufkin soils are gray with heavy, very impervious plastic gray and mottled subsoils. These soils are generally lower in agricultural value than the Norfolk and Orangeburg soils perhaps on account of the nature of the subsoils. These soils are found in Houston, Lamar, and Travis Counties, of the areas studied.

Chemical Characteristics. The Lufkin soils are constantly low in phosphoric acid and nitrogen, and variable in lime. They resemble the Norfolk soils in their composition, and their lower crop value is probably due to the nature of the subsoil. These contain a small amount of organic matter.

Susquehanna series. These are gray and brown surface soils with heavy plastic mottled subsoils. They differ from the Lufkin series in the color of subsoil. They are generally of low productiveness.

Chemical Characteristics. As the Susquehanna soils were found in only two areas (Houston and Hays counties) there is not a sufficient basis for general statements. The content of insoluble matter is decidedly lower in Hays than in Houston county. These soils are slightly better supplied with plant food than the corresponding Lufkin soils.

Houston series. These are black calcareous prairie soils, very productive, and durable. They are among the best soils in the state. Some of them have been in cultivation forty or fifty years without fertilizer, and though some of these have decreased somewhat in fertility, they are still productive. They were found, in the areas surveyed, in Lamar, Hays, Travis and Bexar Counties. They are of general occurrence in the east-central portion of the state.

Chemical Characteristics. These soils are generally well supplied with nitrogen and lime, often containing considerable amounts of the latter. They are variable in phosphoric acid, sometimes very low, but generally well supplied. They contain a good supply of organic matter.

These soils appear to owe their productiveness to their content of lime and organic matter, and nitrogen. Some of these soils will become deficient in phosphoric acid. The average composition is given in Table 3.

Yazoo Soils. These soils are bottom land, generally subject to overflow, and very productive. The soils are mapped in only two areas, Anderson and Travis counties.

General Characteristics. Since only two soils were analyzed nothing of general application can be said. These soils are well supplied with plant food, particularly lime, and phosphoric acid. They contain less nitrogen than the Houston soils.

General Observations.

It appears that the different groups of soils have definite chemical characteristics, which are related to their productiveness. The Norfolk soils contain less plant food and are less productive, than the corresponding Orangeburg soils. The Houston and Yazoo soils, which are very productive, are well supplied with plant food and lime. The Susquehanna and Lufkin soils, which have low crop values, are low in plant food.

The individual soils in the series vary to some extent, as may be expected, but the group characteristics generally prevail.

Table 4 shows the composition of the individual soils in some of the series.

Table 4—Composition of Soil Types.

Norfolk Series.

	Phosphoric acid.	Nitrogen	Potash	Lime	Insoluble.
N. Sand Houston County	.01	.03	.10	.28	98.21
" Anderson County	.02	.03	.07	.05	97.92
" Bexar County	.02	.04	.05	.04	97.95
N. fine sand, Houston County	.01	.05	.13	.10	97.13
" " Anderson Co.	.02	.01	.07	.07	97.68
N. fine sandy loam, Houston C.	.02	.03	.18	.09	97.93
" Anderson Co.	.01	.03	.13	.05	96.48
Norfolk silt loam, Bexar County	.02	.09	.17	.05	92.08

Orangeburg Series.

	Phosphoric acid.	Nitrogen	Potash	Lime	Insoluble.
O. fine sand,					
Houston County	.03	.03	.14	.14	96.75
Bexar County	.02	.05	.25	.18	95.06
O. sandy loam,					
Lamar County	.05	.04	.25	.12	94.35
O fine sandy loam,					
Houston County	.05	.03	.71	.10	88.34
Anderson County	.03	.04	.13	.02	94.87
Lamar County	.02	.03	.76	.06	97.12
O. Clay, Anderson County	.06	.08	.22	.23	84.52
O. Clay Bexar County	.09	.11	.45	.35	77.33
O. Silt Loam,					
Lamar County	.12	.20	.78	1.52	78.19

Houston Series.

	Phosphoric acid.	Nitrogen	Potash	Lime	Insoluble.
H. Black Clay—					
Lamar County	.05	.13	.39	1.05	65.48
Travis County	.07	.12	.29	5.66	65.16
Bexar County	.08	.12	.32	1.16	72.93
Hays County	.08	.13	.20	19.61	42.07
H. Clay, Lamar County	.02	.10	.19	.35	85.51
H. Clay, Hays County	.09	.28	.04	9.32	38.75
H. Black Loam, Bexar Co.	.06	.18	.80	3.06	70.77
H. Loam, Hays Co.	.01	.18	.29	.37	85.24

Lufkin Series.

	Phosphoric acid.	Nitrogen	Potash	Lime	Insoluble.
L. Fine Sand, Houston Co	.03	.03	.11	.15	97.77
L. Fine Sandy Loam—					
Travis County	.02	.04	.11	.91	95.53
L. Clay, Houston Co.	.01	.05	.14	.43	94.15
L. Clay, Lamar Co.	.03	.10	.13	.07	90.31

Susquehanna Series.

S. Fine Sandy loam—					
Houston County	.03	.04	.11	.05	95.10
Hays County	.04	.09	.34	.70	
S. Clay, Houston County	.03	.03	.28	.13	90.08

The soils vary considerably in depth. Taking 12 inches, and 3½ millions pounds as the weight per acre, the average quantity of plant food in the surface soils of the different types is given in Table 5. Some of these soils are considerably deeper, and others less deep, than 12 inches.

Table 5. Plant Food in the Soil Series, in Pounds Per Acre.

	Phosphoric Acid.	Nitrogen,	Potash.
Norfolk Soils	700	1,750	4,200
Orangeburg Soils	1,750	2,100	12,950
Lufkin Soils	700	1,750	3,850
Susquehanna Soils	1,050	2,450	7,700
Houston Soils	2,100	4,900	11,800
Yazoo Soils	3,850	2,800	13,650

Table 6 shows the number of crops of cotton (250 lbs. lint) which each ingredient in the top 12 inches of the soil can produce, when only the lint and seed are removed. Thus the Norfolk soils contain enough phosphoric acid for 100 crops cotton, nitrogen enough for 110 crops, and potash for 470 crops, assuming that all the fertility in leaves, stalks, etc., returns to the field. The plant food would indeed last for a longer time than indicated, because it will be converted into active forms at a diminishing rate as the quantity present decreases, and a correspondingly smaller crop will result.

The table, No. 6, shows, also, the number of crops of corn (40 bushels) that can be removed, if the entire crop is taken away. If a portion of the plant is returned, the stores in the soil would last longer. Corn, however, would exhaust the soil more rapidly than cotton.

Table No. 6. Number of Crops the Plant Food in the Soil Will Supply.

	Phosphoric Acid.	Nitrogen,	Potash.
Cotton (seed removed)—			
Norfolk Soils	100	110	470
Orangeburg Soils	250	132	1,440
Lufkin Soils	100	110	430
Susquehanna Soils	150	153	855
Houston Soils	300	306	1,325
Yazoo Soils	550	175	1,516
Corn (entire crop removed)—			
Norfolk soils	28	29	100
Orangeburg Soils	70	35	308
Lufkin Soils	28	29	91
Susquehanna Soils	42	41	183
Houston Soils	84	82	290
Yazoo Soils	154	56	325

In considering this table, we must remember that a quantity of nitrogen is lost every year in the water which passes through the soil, perhaps sometimes as much as is taken up in the crop. Losses of potash and phosphoric acid in this way are small.

We find, then, that for either corn or cotton, if all the plant food in the soil were equally active, nitrogen would become deficient first, phosphoric acid second, and potash last of all.

SOILS OF HOUSTON COUNTY.*

Seventeen types of soils are found in Houston County, but a number of these are of limited distribution. The chief soils may be divided into four series, namely: the Norfolk series, the Orangeburg series, the Lufkin series, and the Susquehanna series.

Norfolk Series.

The Norfolk series are light colored upland sandy soils, with a yellow clay or sandy clay subsoil, usually with good drainage. These soils are adapted to special purpose crops, rather than to general farming. This series comprises the most important truck soils of the coastal plain. The Norfolk soils found in Houston county are described as follows:

Norfolk Sand is a loose gray sandy soil about 12 inches deep, with a yellow sand subsoil. There are only a few small areas of this soil in Houston County. It is considered a good truck soil and is especially suited to sweet potatoes and watermelons, though it is not so well adapted to general farm crops.

Norfolk Fine Sand is a fine loamy sand, gray on the surface, about 10 inches deep, with a yellow fine sand subsoil. It is especially adapted to early truck crops. Grapes, sweet potatoes, and melons do especially well, also plums and berries. This soil is also used for cotton and corn. It is more productive than the Norfolk sand, but deteriorates in a few years.

Norfolk Fine Sandy Loam is a loamy fine gray sand, 12 to 30 inches deep, with a yellow fine sandy loam subsoil. It has good drainage. It is especially adapted to truck, to some extent to peaches, and to a variety of small fruits. Cotton and corn are also grown, and some oats.

Orangeburg Soils.

The Orangeburg soils are gray to brown upland soils underlain at a depth of three feet or less by a red or yellowish red sandy clay. The red color of the subsoils distinguishes the Orangeburg series from the Norfolk series. The red soils appear to possess a higher producing power, and are geuerally stronger than the corresponding soils of the Norfolk series.

Orangeburg Fine Sand of Houston County is a red or gray loamy fine sand underlain by a sandy red clay or clay loam. It occupies only a limited area in this county. It is probably best adapted to fruits and truck, though cotton and corn are also grown.

* A description and map of these soils is published by the Bureau of Soils of the U. S. Department of Agriculture," on Soil Survey of Houston County, Texas," by William T. Carter and A. E. Kocher,—"Advance Sheets—Field Operation of the Bureau of Soils, 1905"

Orangeburg Fine Sandy Loam of Houston County is a red, brown, or gray fine loamy sand, 4 to 15 inches deep, underlaid by rather heavy red sandy clay. It often contains 1 to 29 per cent red sandstone fragments and is known as "red-land," or "red gravelly land." It has good surface drainage, and is the strongest and most productive upland soil in this area. It is adapted to tobacco, peaches, truck, cotton and corn. It is probably the earliest soil in the county.

Orangeburg clay occupies a limited area in this county. We did not secure a sample of it for analysis.

Lufkin Series.

The Lufkin soils are gray soils with heavy, very impervious, plastic gray and mottled subsoils. The soils are generally lower in agricultural value than those of the Norfolk and Orangeburg series.

Lufkin Fine Sand of Houston County is a gray fine silty sand, about 10 inches deep, with a subsoil of much the same color and texture to a depth of 36 inches. It occurs in large areas in this county on rolling upland. It is used mainly for cotton and corn, and is adapted to fruits, truck and sugar cane. The soil declines in productiveness after two or three years unless manured.

Lufkin Clay of Houston County is a gray silty or fine sandy loam, 3 to 8 inches deep underlain by a heavy gray or mottled gray and yellow clay. This soil occupies low areas with poor surface drainage. When first cleared it is cold and sour, but produces well after two or three years in cultivation. Cotton and corn are grown and some oats.

Susquehanna Series.

The Susquehanna soils are gray and brown surface soils, with heavy plastic, red mottled clay subsoil. The soils are unusually of low crop-producing value.

Susquehanna Fine Sandy Loam of Houston County is a gray fine sandy loam, 8 to 20 inches deep, underlain by a heavy mottled red and gray clay with a peculiar greasy feel. It is a rolling land with good surface drainage. It is a productive soil, adapted to cotton and corn; and peaches and small fruits and vegetables make good yields.

Susquehanna Clay is a gray fine sandy or silty loam, 6 to 8 inches deep, with a heavy impervious red clay subsoil. It is known as "post oak land." This land is not well drained. The best yields are obtained only after two or three years cultivation.

Other Soils.

Other soils which appear in this area, which we have not subjected to analysis, are as follows. Most of these occur to a very limited extent:

Wabash Clay,
Yazoo Loam,
Crockett Loam,
Houston Black Clay,
Sharkey Clay,
Yazoo Sandy Loam.

DESCRIPTION OF SAMPLES.

No. 312 Norfolk sand. Taken three miles northwest of Grapeland, on Bud Herrod's place.

No. 314 Norfolk fine sand. Taken from uncultivated land 2½ miles northwest of Grapeland on M. J. Baker's place.

No. 316 Norfolk fine sandy loam. Taken 2½ miles Northwest of Grapeland on M. J. Baker's place.

No. 322 Orangeburg fine sand. From land of A .W. Ellis, ½ mile west of court house, Crockett. Land in cultivation 40 years.

No. 310 Orangeburg fine sandy loam. From the slope of Cook's Mountain, 2½ miles northwest of Crockett, on A. W. Wootter's farm.

No. 318 Lufkin fine sand, from the farm of J. H. Sallas, Lovelady.

No. 320 Lufkin clay, from Emainer's place, Lovelady.

No. 306 Susquehanna fine sandy loam. From J. A. Wright's farm, three miles east of Crockett, land in cultivation several years.

No. 308 Susquehanna clay. From uncleared land three miles north west of Crockett, Texas.

COMPOSITION OF HOUSTON COUNTY SOILS.

The chemical composition of the soils of Houston county is given in Table 7.

All of these soils are low in phosphoric acid and nitrogen. The two Orangeburg soils are better supplied with phosphoric acid than the other soils, and, since they contain sufficient lime, this supply may last for some time.

All the soils in this area appear to contain sufficient potash except the Susquehanna clay, and only the Lufkin clay and the Susquehanna soils are low in lime.

There is a remarkable resemblance in the chemical composition of corresponding types of soil in Anderson County and Houston County.

The soils of Houston County appear to be better supplied with lime and potash than the soils of Anderson County.

TABLE NUMBER 7—PERCENTAGE COMPOSITION OF HOUSTON COUNTY SOILS.

	Norfolk Sand		Norfolk Fine Sand		Norfolk Fine Sandy Loam		Orangeburg Fine Sand		Orangeburg Fine Sandy Loam		Lufkin Fine Sand		Lufkin Clay		Susquehana Fine Sandy Loam		Susquehana Clay	
	Surface Soil		Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil		Surface Soil	Subsoil	Surface Soil		Surface Soil	Subsoil
Phosphoric Acid	.01	....	.01	.03	.02	.02	.05	.03	.05	.09	.03	....	.01	.07	.03	....	.02	.03
Nitrogen	03	....	.05	.02	.03	.05	.03	.04	.03	.03	.03	....	.05	.05	.04	....	.07	.03
Potash	.10	....	.13	.16	.18	.31	.14	.28	.71	.35	.11	....	.14	.24	.11	....	.20	28
Lime	.28	....	.10	.05	.09	.12	.14	1.42	.10	. 8	15	....	.43	.28	.05	....	.29	.13
Magnesia	.31	....	.03	.09	.11	.2	.06	.16	.08	.18	.63	....	.07	.12	.09	....	.29	.39
Carbon Dioxide	.12	....	.00	.08	.03	....	.03	....	.01	.02	.03	....	.41	....	.01	....	.01	.01
Sulphur Trioxide	Tr	....	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	....	.02	.04	Tr	....	Tr	Tr
Alumina.... / Oxide of Iron	.54	....	1.25	1.20	.82	14.93	1.84	9.17	8.54	21.18	.89	....	3.36	12.49	2.87	....	4.92	17.18
Insoluble and Soluble Silicia	98.21	....	97.13	98.05	97.93	76.17	96.75	83.31	88.34	67.95	97.77	....	94.15	75.37	95.10	....	90.08	69.51
Loss of Ignition	.61	....	1.01	.53	.63	5.12	.65	3.09	1.01	5.54	.98	....	1.96	5.14	1.37	....	2.55	5.31
Moisture.......	.22	....	.17	.12	.24	2.45	.50	2.30	.49	4.01	.22	....	.41	5.62	.46	....	1.50	6.39

DETAILED DISCUSSION OF HOUSTON COUNTY SOILS.

Table 8 contains the interpretation of the results of the analyses according to the standards already mentioned. We would expect these soils to respond to phosphate and nitrogen fertilizers.

The Norfolk soils in the order of their productiveness, beginning with the lowest, are Norfolk sand, Norfolk fine sand, Norfolk fine sandy loam, the first two being nearly the same. There is slightly more phosphoric acid in the most productive soil. The potash increases with the productiveness of the soils. The most productive soils is also the deepest.

The Orangeburg soils are more productive, and contain more phosphoric acid than the Norfolk soils. The more productive of the two soils is the shallower, and is more liberally supplied with phosphoric acid and potash, if we consider the subsoils.

The Lufkin soils are low in phosphoric acid and nitrogen. The more productive soil is shallower and is better supplied with nitrogen and lime than the other.

The Susquehanna soils are low in plant food. The more productive contains more nitrogen and more potash, though not sufficient for a clay soil.

There appears to be some relation between the productiveness of these soils and their chemical composition, when the other characteristics of the soils are considered. The differences do not appear to be large in many cases, however.

Norfolk Fine Sand Needs Phosphoric Acid.

The above cut and those on the following and preceding pages are photographs showing the effects of the different applications of plant food.

TABLE NUMBER 8—INTERPRETATION OF ANALYSES OF HOUSTON COUNTY SOILS.

	Norfolk Sand	Norfolk Fine Sand	Norfolk Fine Sandy Loam	Orangeburg Fine Sand
Phosphoric Acid	Low	Low	Low	Low
Nitrogen	Low	Low	Low	Low
Potash	Sufficient	Abundant	Sufficient	Sufficient
Lime	Abundant	Sufficient	Sufficient	Abundant
Cotton bales	0.2—0.5	0.3—0.5	0.5—0.8	0.3 to 0.7
Corn bu	15—25	15—25	20 30	20 25
Depth of Soil	12''	10''	12 30''	1[illegible] 36''

	Orangeburg Fine Sandy Loam	Lufkin Fine Sand	Lufkin Clay	Susquehanna Fine Sandy Loam	Susquehanna Clay
Phosphoric Acid	Low	Low	Low	Low	Low
Nitrogen	Low	Low	Low	Low	Low
Potash	Sufficient	Moderate	Moderate	Sufficient	Low
Lime	Sufficient	Sufficient	Low	Low	Low
Cotton bales	0.5 0.8	0.5 0.7	0.5 0.8	0.5 0.8	0.3 0.8
Corn	25 40	15 25	20 30	20 30	25 35
Depth of Soil	4 15''	10''	3 8''	8 20''	6 3''

POT EXPERIMENTS.

Table 9 contains the results of pot experiments with Houston county soils. The table shows the yield of corn (dry matter) produced in pots containing nitrogen and potash (NK), phosphoric acid, nitrogen and potash (PNK), phosphoric acid and nitrogen (PN) and phosphoric acid and potash (PK). By comparing the crop produced without a given fertilizer ingredient with the crop from the pot receiving a complete fertilizer, the effect of the ingredients in question can be ascertained.

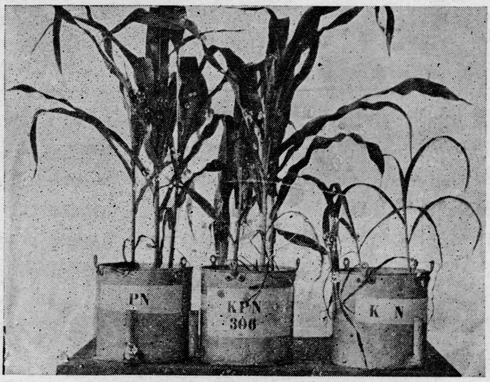
Norfolk Fine Sandy Loam.

Table 9—Pot Experiments with Corn on Houston County Soils.

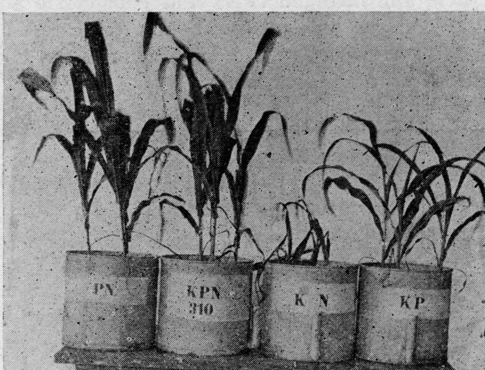
Laboratory Number	Crop per Pot. NK Gm	PNK Gm	PN Gm	KP Gm
314 Norfolk fine sand	1.6	10.7	9.8	11.9
316 Norfolk fine sandy loam	1.9	12.1	9.8	6.9
306 Susquehanna fine sandy loam	1.9	10.9	12.4	—
310 Orangeburg fine sandy loam	2.9	6.1	5.6	5.4
318 Lufkin fine sand	3.4	4.9	5.5	3.2

The only one of these soils which appears to need potash is the Norfolk fine sandy loam. This soil, according to the chemical analysis, contains an abundance of potash.

All the soils tested respond to applications of phosphoric acid.

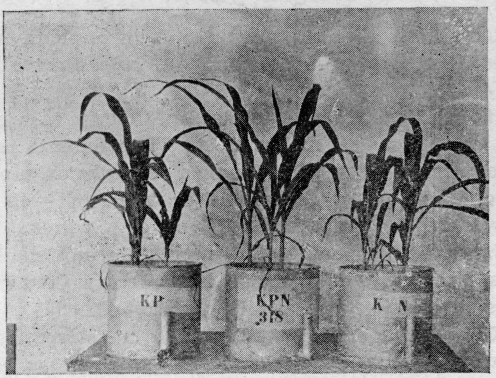


Susquehanna Fine Sandy Loam.



Orangeburg Fine Sandy Loam.

An application of phosphoric acid is denoted by P; potash by K; nitrogen by N.



Lufkin Fine Sand.

ACIDITY.

Two of these soils were tested for acidity by the salt water method. No. 320, Lufkin clay, has an acidity equivalent to 187 parts per million of lime, and would require 650 lbs. per acre of quick lime to neutralize it to the depth of 12 inches. No. 306, Susquehanna fine sandy loam was found to be slightly acid, equivalent to 32 parts lime per million.

SOILS OF ANDERSON COUNTY.*

Ten types of soils were mapped in Anderson County, six of which have been subjected to chemical examination. The chief soils of Anderson county may be divided into three series, the Norfolk series, the Orangeburg series, and the Yazoo series.

NORFOLK SOILS.

The Norfolk soils are are light colored upland sandy soils, with a yellow sand or sandy clay subsoil. The following is the description of the Norfolk soils in this area.

Norfolk sand is a loose sandy soil about 10 inches deep with a yellow sandy subsoil, occupying high areas. Potatoes, peaches, and small fruits do well. The crops usually grown are cotton and corn, and some vegetables, peaches, plums, etc. When first cultivated, the yields are fair but the soil deteriorates in a few years.

Norfolk fine sand is a light brown or gray fine sand, 12 inches deep, with a yellow fine sand subsoil, occupying rolling land. It is adapted to truck crops, small fruits, and peaches. The crops usually grown are cotton, corn, potatoes, melons, vegetables, peaches, etc. This soil is more productive than the Norfolk sand, but deteriorates in a few years.

Norfolk fine sandy loam is a gray or light brown fine sandy loam, 15 or 24 inches deep, with a yellow clay subsoil, appearing as rolling upland wth good surface drainage. This soil is adapted to truck farming and fruit growing. The principal crops are corn and oats, while near railroads some vegetables and fruits are grown for market.

[* A full description of these soils, with a map showing the location of the types, is published by the Bureau of Soils, U. S. Department of Agriculture, "'Soil Survey of Anderson County" by William T. Carter and A. E. Kocher-Advance Sheets—Field Operations of the Bureau of Soils, 1904.]

Orangeburg Soils.

The Orangeburg soils are red, brown or gray upland soils, with red sandy clay or red clay subsoils. As a general rule, they are found to be more productive than Norfolk soils.

Orangeburg fine sandy loam of Anderson County is a red, brown or gray fine sandy loam, 6 to 18 inches deep. The subsoil is a red sandy clay. The soil contains 5 to 30 per cent of a ferruginous sandstone gravel. The local name for this type is "chocolate," or "mulatto" soil.

This soil appears to be the best peach soil of the area. It is also well adapted to the production of corn, cotton, vegetables and small fruits, being probably the most productive upland soil in Anderson County. It is easily cultivated and its productivity is readily maintained.

Orangeburg Clay of Anderson County is a compact red, or brown sandy loam of fine texture, about 4 inches deep. The subsoil is a heavy red clay, sometimes containing enough sand to give it the properties of a heavy fine sandy loam. The soil contains 15 to 70 per cent of small iron concretions and fragments of sandstone. In Anderson County a great deal of the surface soil of this type has been removed by erosion. The largest area is near Palestine. In small areas it usually occurs in steep and rugged slopes, adjacent to streams. The soil is probably derived from weathering of greensand marl. Probably not more than 5 per cent of the type is cultivated. The typical soil is well adapted to cotton, corn and oats, and fair yields of wheat can be grown.

Yazoo Soils.

This is level or nearly level bottom land along the Trinity river, 3 or 4 miles wide, subject to overflow.

Yazoo Clay of Anderson County is a dark-drab or sticky clay, 12 inches deep, with a similar subsoil. This is a rich and productive type, but the greater part is uncultivated. When cultivated, it is especially adapted to cotton and corn, producing one bale of cotton, or even more, per acre, and from 60 to 70 bushels of corn. At present the Yazoo clay is utilized for cattle grazing and raising of hogs.

Description of Samples.

No. 172. Norfolk sand. Taken from an uncleared area supporting a natural growth of pine, with some oak.

No. 174. Norfolk fine sand. Taken from an uncleared area, about 5 miles S. W. of Palestine, natural growth of oak and hickory.

No. 176. Norfolk fine sandy loam. Taken from a field in cultivation to cotton and corn for several years, with no fertilizer or manure, about 3 miles west of Palestine.

No. 180. Orangeburg fine sandy loam. Taken from a field which had produced corn and cotton a number of years without the use of fertilizers of any kind, about one mile from Palestine.

No. 178. Orangeburg clay from an old cleared field.

No. 182. Yazoo clay, taken from a field in natural forest growth, near Bonner's Ferry, about 4 miles southwest of Tucker. This type is cultivated practically none, and is utilized principally for grazing.

TABLE 10—PERCENTAGE COMPOSITION OF ANDERSON COUNTY SOILS.

	Norfolk Sand		Norfolk Fine Sand		Norfolk Fine Sandy Loam		Orangeburg Fine Sandy Loam		Orangeburg Clay		Yazoo Clay	
	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	Subsoil
Phosphoric Acid ..	.02	.02	.02	.01	.01	.03	.03	.04	.06	.04	.14	.13
Nitrogen.........	.03	.01	.03	.03	.03	.04	.04	.05	.08	.04	.13	.09
Potash...........	.07	.07	.10	.30	.13	.29	.13	.26	.22	.50	.50	.56
Lime.............	.05	.07	.06	.07	.04	.05	.02	.11	.23	.22	3.14	1.56
Magnesia.........	.05	.13	.07	.06	.05	.14	.04	.17	.22	.42	.75	.50
Carbon Dioxide ...	....	.01	....	.02	....	.01	.01	.01	.04	.00	1.16	.35
Sulphur Trioxide..	.11	.09	....	....	....	.01	....	....	Tr	Tr	Tr	Tr
Alumina ..... / Oxide of Iron .	.83	.88	1.07	1.35	1.42	13.18	.52	14.49	8.30	18.70	17 76	15.78
Insoluble and Soluble Silicia.......	97.92	97.81	97.68	97.70	96.48	78.28	94.87	78.14	84 52	70.26	59.08	68.80
Loss on Ignition...	.96	.78	.91	.65	1.15	4.28	1.56	4.11	3.93	5.08	9.97	6 33
Moisture....	.20	.20	.14	.19	.19	3.06	.33	1.95	3.25	4.71	7.18	6.73

Composition of Anderson County Soils.

The chemical composition of the soils of Anderson County is shown in Table 10.

All of these soils are low in **phosphoric acid,** and all, except the Yazoo clay, in **nitrogen.** It can be expected that after a few years of cultivation, these soils will respond to applications of phosphatic and nitrogenous fertilizers. The Yazoo clay and Orangeburg clay are more liberally supplied with phosphoric acid than the other soils, the Yazoo clay being the better in this respect.

As regards **potash,** the Orangeburg soils are better supplied than the Norfolk soils. The Norfolk sand and the Orangeburg clay are low in potash.

These soils are low in **lime,** with the exception of Yazoo clay, which contains an abundance.

The soils in this area are low in organic matter, and should receive benefit from manure, or green crops ploughed under. Cowpeas should be beneficial on account of the nitrogen which they secure from the air. It is the experience of several farmers on these soils that cowpeas improve the soils decidedly.

Detailed Discussion of Anderson County Soils.

Table 11 contains the interpretation of the results of the analyses according to the standards already mentioned. We would expect these soils to respond to application of phosphatic and nitrogenous fertilizers, and probably to receive benefit from lime.

The Norfolk soils, in the order of their productiveness, beginning with the lowest, are, Norfolk sand, Norfolk fine sand, and Norfolk fine sandy loam. There is no relation between this order and the amount of phosphoric acid present. The nitrogen in the surface soils is equal in percentage, but the depth of the soil increases with the productiveness, and the nitrogen in the subsoil is in order 0.01, .03, .04 per cent. The potash in the surface soil is also in the order of the productiveness. In these three soils, at least, there appears to be relation between productiveness, depth of soil, and concent of nitrogen and potash.

The Orangeburg fine sandy loam appears to contain more phosphoric acid and nitrogen than the Norfolk fine sandy loam, and is known to be a more productive soil. The Orangeburg clay is less productive than the Orangeburg fine sandy loam; it contains more nitrogen, phosphoric acid, and potash in its surface layer, but the surface soil is shallow (4 inches) and clay soils require more plant food than loams.

The Yazoo clay is a most productive and lasting soil, and it is well supplied with plant food.

In the soils of this area, there appears to be a definite relation between the chemical composition of the soils, their productiveness, and their depth.

Table 11—Interpretation of Analyses of Anderson County Soils.

	Norfolk sand	Norfolk fine sand	Norfolk sandy loam	Orange-burg fine sandy loam	Orange-burg clay	Yazoo clay
Phosphoric Acid...	Low	Low	Low	Low	Low	Fair
Nitrogen	Low	Low	Low	Low	Low	Good
Potash	Low	Good	Good	Good	Low	Good
Lime	Low	Low	Low	Low	Low	Abundant
Depth of Soil......	10"	12"	15-24"	6-18"	4"	12"
Yield of cotton (bales)	¼-½	0.3-0.5	0.3-0.7	½-¾	½-¾	1
Yield of Corn crop (bu.)	15-25	20-30	20-40	30-40	25-40	60-70

POT EXPERIMENTS.

Pot experiments were made with all these soils, as already described Unfortunately there was not enough soil to make complete tests. The results are presented in Table No. 12. Experiments with Soil 174, 176, 178 and 180 were carried out at the same time, and are directly comparable. Experiments with Soils 172 and 182 were conducted on another crop and at another time, but the crop (corn) did not grow well on Soil 182 Yazoo clay), and the crop harvested was very small, and the differences between the pots were within the limits of error on this soil.

Table No. 12. Pot Experiments With Anderson County Soils.

	Gram Crop per Pot			
	NK	PNK	PN	KP
176—Norfolk fine sandy loam—cowpeas	14.4	19.5	20.7	
180—Orangeburg fine sandy loam—cowpeas	15.7	21.4	20.1	
174—Norfolk fine sand—cowpeas	17.1	22.0	19.6	
178—Orangeburg clay—cowpeas	20.9	24.3	20.9	
172—Norfolk sand—corn	3.0	9.7	6.5	7.2
172—Norfolk sand—cowpeas	10.5	10.2	5.9	7.5

Norfolk Sand.

The pot marked PNK received phosphoric acid, potash and nitrogen; Pot NK received nitrogen and potash, and the difference between this pot and the first pot named shows the effect of phosporic acid. Pot PN received phosphoric acid and nitrogen, and the difference between it the pot with the complete fertilizer shows the effect of potash.

The Norfolk sand and Orangeburg clay appear to be deficient in potash; and this is in accord with the conclusion from the chemical analysis. The Norfolk fine sand may possibly be slightly deficient in this substance. The other soils tested appear to contain enough potash for corn.

The soils are arranged in the table in the order of their response to fertilization with phosphoric acid, beginning with the most responsive. The experiment with Norfolk sand is not directly comparable with the others, since it was made at a different time, but this soil appears to need phosphoric acid for corn, and not for cowpeas.

These experiments are believed to indicate the immediate needs of these soils for active plant food.

The samples of Norfolk sand, Norfolk fine sand, and Yazoo clay, represent virgin soils. The Norfolk fine sandy loam, Orangeburg fine sandy loam, and Orangeburg loam, and Orangeburg clay, were from fields which had been in cultivation some years, without fertilizers. Necessarily, the active plant has been removed to some extent from the latter soils.

Yazoo Clay.

SOIL ACIDITY.

The acidity of the soils of this area was determined by the salt water method, namely, by treatment with a solution of sodium chloride, and titration of the filtrate with standard caustic soda and phenolpthalein indicator.

The results are as follows:

	Acidity (Parts per million of CaO).
172—Norfolk sand	50.
174—Norfolk fine sand	0.
176—Norfolk fine sandy loam	0.
178—Orangeburg clay	0.
180—Orangeburg fine sandy loam	0.

Only one of these soils appeared to be acid by this method, and its acidity is slight and would be removed to the depth of 12 inches by the application of 200 pounds of unslacked lime per acre.

SOILS OF LAMAR COUNTY.*

Eleven types of soils were mapped in the soil survey of this county. The chief soils may be divided into two series: the Orangeburg series, and the Houston series. There is besides a number of miscellaneous types.

Orangeburg Soils.

These soils have already been described. The types found in this area are described as follows:

Orangeburg Sandy Loam is a medium to coarse sandy loam, 8 to 24 inches deep, gray to grayish yellow in color in dry weather and red in wet. The subsoil is a red sandy clay. This soil produces strawberries, potatoes, corn and cotton, and is recognized as the best soil in the area for diversified farming. It is known locally as "red sandy land.'

Orangeburg Fine Sandy Loam is a gray sand of medium to fine texture, 10 to 20 inches deep, with a sandy clay subsoil, mottled red, gray and yellow. It occurs in a strip 2 to 10 miles wide in the northern part of the county. The land washes badly. This is regarded as a poor soil. Cotton, corn and some truck are raised. It is greatly benefited by cowpeas and alfalfa.

Orangeburg Silt Loam is a silt loam of brownish red, or chocolate red color, 6 to 24 inches deep, with a redder or browner subsoil. Cotton, corn and alfalfa are the principal crops; the soil yields an average of a bale of cotton an acre.

Orangeburg Clay is a red loam, or clay loam, eight inches deep, covered with 2 to 4 inches of sand in forested areas. The subsoil is a stiff, tenacious, brown, red, or gray mottled clay loam, or clay. Only a small portion of this soil is under cultivation, and it is regarded as an undesirable soil. Cotton and corn are the principal crops grown.

Houston Soils.

The Houston soils of Lamar County are black prairie soils which occur in the Calcareous prairie regions, and are characterized by a large percentage of lime, especially in the subsoil. These soils are very productive. They are devoted to cotton and corn chiefly, but some of them will produce excellent crops of alfalfa.

Houston Black Clay of Lamar County is a dark brown to a black clay loam or clay, 6 to 10 inches deep, known as "black waxy" land, with a similar subsoil. When dry and well cultivated, it is friable and easily worked, but when wet it becomes gummy and waxy. The entire southern part of Lamar

* [A description and map of this area is published as the "Soil Survey of the Paris area," Report of Bureau of Soils for 1903.]

County is composed of this type of soil. This soil is entirely under cultivation, and is regarded as one of the strongest soils in the area. Cotton and corn are the principal crops, though oats, wheat, alfalfa and onions are sometimes grown.

Houston Clay is a light brown to brown, very fine sandy loam, or silt loam, 0 to 4 inches deep, with a brownish yellow or grayish yellow clay subsoil which usually becomes quite stiff and tenacious at 24 inches. This type is known as "mixed land" and also as "tallow ridge land." The drainage is good. The principal crops are cotton, corn and hay, with some wheat and alfalfa. It is greatly benefited by deeper plowing and the turning under of cowpeas.

Miscellaneous Soils of Lamar County.

Sharky Clay is a grayish-yellow, stiff, waxy, impervious clay, 7 to 12 inches deep, with a stiff, waxy, impervious clay subsoil, reddish yellow to brownish gray in color. When wet the soil is waxy and gummy, but when dry and well cultivated, it is friable and easily worked. It occurs in low flat areas, in bottoms subject to inundations. The soil is very productive, perhaps due to the fact that it is flooded every year. Corn and cotton are the only crops grown.

Lufkin Clay is a gray to grayish yellow, very fine to medium sandy loam, or loam, 10 to 15 inches deep, with a heavy mottled blue, yellow, or red sandy clay. This soil has a tendency to run together in wet weather and to suffer from drought in dry weather. The local name is "Ashy Flats," or "Post-oak Flats." It is used for pasture. Cotton and corn are grown, but the yields are small.

Sanders Loam is a sandy loam, brown or dark brown, or reddish brown in color, with a lighter colored and heavier subsoil. The drainage is poor. It is subject to inundations and most of it poorly drained. Corn and cotton are the principal crops.

TABLE 13 - PERCENTAGE COMPOSITION OF LAMAR COUNTY SOILS.

	Orangeburg Sandy Loam	Orangeburg Fine Sandy Loam	Orangeburg Silt Loam	Orangeburg Clay	Houston Black Clay	Houston Clay	Sharkey Clay	Lufkin Clay	Sanders Loam
	Surface Soil	Surface Soil	Surface Soil	Surface Soil	Surface Soil	Surface Soil	Surface Soil	Surface Soil	Surface Soil
Phosphoric Acid ..	.05	.02	.12	.05	.05	.02	.11	.03	.04
Nitrogen..	.04	.03	.20	.04	.13	.10	.23	.10	.09
Potash...........	.25	.76	.78	.40	.39	.19	.83	.13	.12
Lime.	.12	.06	1.52	.08	1.05	.35	1.20	07	.38
Magnesia........	.07	.07	.61	.20	.89	.32	1.25	.11	.25
Carbon Dioxide ...	.03	.01	.01	....	....	.03	.05	.01	.04
Sulphur Trioxide .	.01	....	.. . ..	....	.05	.01	.08	.04	03
Alumina and	1.72	1.62	9.14	10.75	16.57	2.47	7.24	2.42	2.02
Oxide of Iron	1.72					1 96	3.36	.87	1 40
Manganese oxide..	.04	....	....	....	....	.05	.. ..	......	....
Insoluble and Soluble Silicia.	94.35	97.12	78.19	81.61	65.48	85.51	70.28	90.31	90.66
Loss on Ignition ..	1.48	.31	6.80	2.97	9 17	4.75	9.62	3.83	3 38
Moisture.. . ..	.51	.76	3.21	3.98	6.69	3.70	5 35	2.25	1.91

COMPOSITION OF LAMAR COUNTY SOILS.

The composition of Lamar County soils is given in table 13, and the interpretation of the analyses in table 14.

Phosphoric acid is low in the Orangeburg fine sandy loam, the Orangeburg clay, the Houston clay, Lufkin clay, and the Sanders loam. These are all considered poor soils with the exception of the Houston clay. The Houston clay, however, is shallow, but well supplied with lime. It is possible that the subsoil supplies more phosphoric acid than the surface soil. Unfortunately we did not receive a sample of subsoil for analysis.

Nitrogen is low in the Orangeburg sandy loam, the Orangeburg fine sandy loam, and the Orangeburg clay. The first soil is locally considered good, the last two poor. The first soil contains sufficient lime,

Potash is low in the Houston clay and Lufkin clay, the first being a good soil, the second a poor soil.

Lime is low in the Orangeburg fine sandy loam, Orangeburg clay, and Lufkin clay, all of which are locally considered poor soils.

It appears that the chemical composition and productiveness of these soils are in accord. The Houston black clay is low in plant food, but appears to be productive on account of the organic matter and lime which it contains in abundance.

Table 14.—Interpretation of Analyses of Soils of Lamar County.

	Orangeburg sandy loam	Orangeburg fine sandy loam	Orangeburg silt loam	Orangeburg clay
Phosphoric Acid.	Fair	Very Low	Good	Low
Nitrogen	Low	Low	Very Good	Low
Potash	Good	Rich	Rich	Fair
Lime	Sufficient	Low	Abundant	Low
Depth of Soil	8-24"	10-20"	6-24"	8"
Yield of Cotton (bales	½	¼-¾	1	0.3
Yield of Corn (bu.)	25	10-25	35-40	15
Remarks.	Considered good	Considered poor.	Very Good	Considered undesirable.

	Houston Black Clay	Houston Clay	Sharkey Clay	Lufkin Clay	Sanders Loam
Phosphoric Acid	Fair	Low	Rich	Low	Low
Nitrogen	Good	Good	Rich	Good	Good
Potash	Fair	Low	Rich	Low	Sufficient
Lime	Abundant	Fair	Abundant	Low	Abundant
Depth of Soil	6-10"	0-4"	7-12"	10-15"	——
Yield of Cotton (bales)	1	½-0.6	¾-1	0.2-¼	½
Yield of Corn (bu.)	40-50	30	40	12-15	45
Remarks.	Very good.	A good soil	Very productive.	Poor	Drainage poor.

ACIDITY.

Three soils of this area (low in lime) were tested for acidity by the salt water method, with results as follows:

125. Orangeburg fine sandy loam, acidity not present.

100 Orangeburg clay, acidity equivalent to 355 parts lime per million or requiring 1250 lbs. quicklime per acre to neutralize it to the depth of 12 inches.

129 Lufkin clay, acid equivalent to 180 parts lime per million or requiring 630 lbs. lime per acre to neutralize it to the depth of 12 inches.

Pot Experiments. See under Travis county, Page 36.

SOILS OF TRAVIS COUNTY.*

Samples of only four of the 9 types of soil found in the Austin area were examined chemically. The Austin area includes parts of Williamson, Bastrop, Caldwell and Hays counties, as well as most of Travis. The soils which were subjected to analyses are as follows:

Houston black clay of Travis County is a dark brown to black prairie soil 12 inches deep, with a stiff, tenacious light brown clay subsoil. The soil becomes loose and friable under cultivation, but is very stiff and tenacious when wet. Cotton, corn, and sorghum and potatoes are grown and produce good crops when the season is favorable.

Yazoo sandy loam is a grayish to light brown fine sandy loam 0 to 15 inches deep, with large silt content, which grades into a compact brown subsoil. It occupies the bottom lands of the Colorado River, but is seldom overflowed. It is productive soil, the crops grown being cotton, corn and sorghum.

Travis gravelly loam is a coarse sandy loam 10 to 12 inches deep containing a large amount of rounded gravel, with a coarse sand and gravel subsoil cemented by clay. It has little agricultural value, and appears best adapted to melons and fruit trees.

Lufkin fine sandy loam is a fine sandy loam 12 inches deep, gray to brownish red in color, with a stiff, sticky, red or brown laminated clay subsoil. It occurs on hills and is liable to injury from drought. Cotton, corn sorghum, oats, fruits, potatoes, and vegetables are produced. The soil is productive.

* A description and map of the soils of this area are published by the Bureau of Soils of the U. S. Department of Agriculture as "Soil Survey of the Austin Area, Texas" by A. W. Mangum and H. G. Belden, (Advance sheets—Field Operatins of the Bureau of Soils, 1904.)

Table 15—Percentage Composition of Travis County Soils.

	Houston black clay Surface Soil	Houston black clay Subsoil	Yazoo sandy loam Surface Soil	Yazoo sandy loam Subsoil	Travis gravelly loam Surface Soil	Travis gravelly loam Subsoil	Lufkin fine loam Surface Soil	Lufkin fine loam Subsoil
Phosphoric acid	.07	.06	.07	.08	.04	.04	.02	.02
Nitrogen	.12	.08	.03	.03	.13	.07	.04	.04
Potash	.29	.35	.28	.06	.52	.65	.11	.31
Lime	5.66	8.51	10.60	13.01	1.47	.76	.91	.45
Magnesia	.68	.68	1.06	.64	.16	.12	.10	.24
Carbon Dioxide	3.78	5.75	5.00	5.16	.99	.44	.46	.09
Sulphur Trioxide	.09		.05			.01	.02	
Alumnia and	4.35	9.07	3.67	7.43	15.06	19.08	.97	12.46
Oxide of Iron	2.10		1.68				.22	
Insoluble and Soluble Silicia	65.16	59.54	64.33	63.98	67.21	63.07	95.53	77.65
Loss on Ignition	10.89	8.79	10.58	6.53	7.80	7.75	1.78	4.10
Moisture	6.88	6.41	2.31	2.23	6.42	7.81	.51	4.45

CHEMICAL COMPOSITION.

The chemical composition of the Travis county soils is given in Table 15 and the interpretation of results in Table 16.

Phosphoric acid is low in the Travis gravelly loam and Lufkin fine sandy loam. Both of these have low crop values.

Nitrogen is low in the Yazoo sandy loam and the Lufkin fine sandy loam. The former soil is productive, the latter is not.

Potash appears to be sufficient in all the soils, and so is lime.

In this case, as in other areas, there appears to be a relation between the crop values of the soils, and their chemical composition.

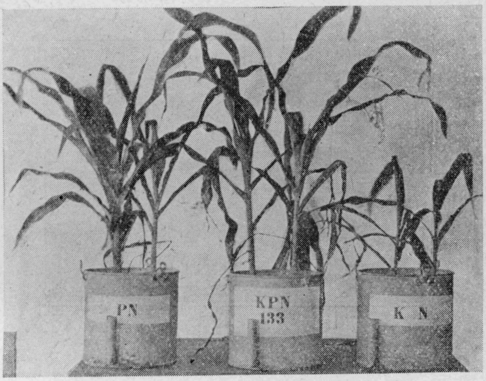
The Houston clay of this area is considerably richer in phosphoric acid and lime than the Houston clay of Lamar county..

Table 16—Interpretation of Analyses of Travis County Soils.

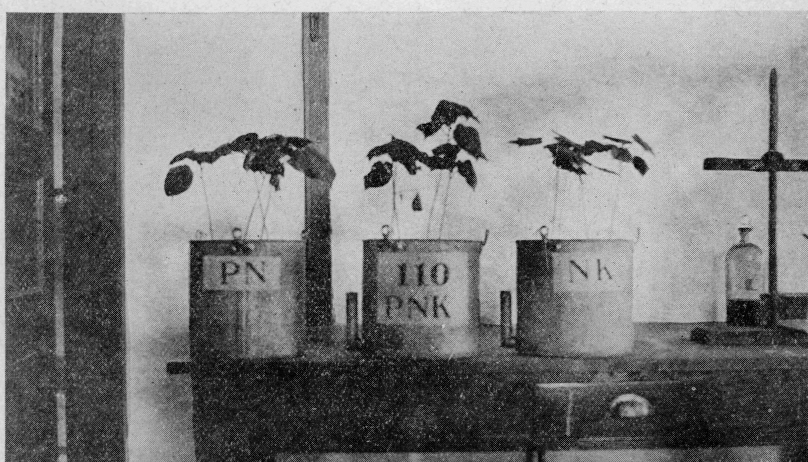
	Houston black clay	Yazoo sandy loam	Travis gravelly loam	Lufkin fine sandy loam
Phosphoric Acid	Good	Good	Low	Low
Nitrogen	Good	Low	Good	Low
Potash	Good	Sufficient	Good	Sufficient
Lime	Much	Much	Abundant	Sufficient
Depth of Soil	12"	0-15"	10-12"	12"
Yield of Cotton	½-¾	½-¾	1-6-1-5	¼-1-3
Yield of Corn	20-25	40-50	8-10 bu.	15
Local opinion	Fertile	Good corn soil	Little value too porous	Droughty

Table 17.—Pot Experiments with Soil of Lamar and Travis Counties.

Laboratory Number		N	Crops per pot NK Gm	PNK Gm	PN Gm	KP Gm
129	Lufkin clay (Lamar)	Cotton	0.9	3.3	2.7	
133	Sanders loam (Lamar)	Corn	2.5	11.9	9.1	9.7
108	Yazoo sandy loam (Travis)	Cotton	2.9	6.1	5.6	
110	Houston Black Clay (Travis)	Cotton	4.2	5.3	5.4	



Sanders Lcam.

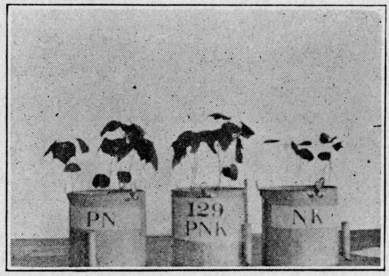


Houston Black Clay.

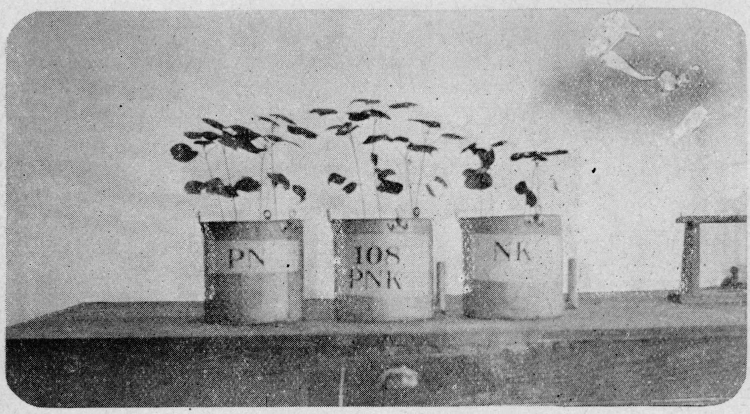
The results of pot experiments on two soils each of these areas are given in Table 17.

The experiments do not indicate a deficiency of potash except with Sanders loam, which contains sufficient potash according to the chemical analysis.

The four soils appear to respond to the fertilization with phosphoric acid, though the result with the Houston black clay is almost doubtful.



Lufkin clay.



Yazoo Sandy Loam.

An application of phosphoric acid is denoted by P., potash by K, nitrogen by N.

SOILS OF BEXAR COUNTY.*

Twelve types of soils were mapped by the U. S. Soils Survey in Bexar County, of which nine have been subjected to analysis by us. There are two soils of the Norfolk series, two of the Houston series, and the others belong to several series.

Norfolk Soils.

The type characteristics of this group have been described in page 14 The soils which occur in this area are described as follows:

Norfolk Sand is a coarse to medium sand, brownish gray to gray in color, 10 inches deep, with a similar subsoil but lighter in color. It is well drained, but of little value on account of the semi-arid conditions of the area.

Norfolk silt loam is a loam of medium texture 6 to 8 inches deep, yellowish brown to dark brown in color. The subsoil is brown to brownish yellow, and a little looser in texture than the surface soil. This soil is much eroded, the water runs off in ravines and gullies and for this reason, is of the least desirable soils in the area. A small acreage is under cultivation.

Houston Soils.

The general characteristics of these soils have been given on page 15. The soils of this area are described as follows:

Houston black loam is a heavy grayish-brown to dark brown loam or clay loam 8 to 15 inches deep. The subsoil has the same texture but changes gradually from brownish gray to yellow at depth of 4 or 5 feet. This soil is friable, easily worked, retains moisture well, endures drought, and is productive. Cotton, corn, and sorghum are grown. This is a desirable soil.

Houston black clay is a heavy clay, 7 inches deep grayish brown to black in color with a similar subsoil but more compact and lighter in color. When dry and properly handled it is friable and easily worked,but when wet it is very sticky and gummy. The areas are flat and poorly drained, the soil is droughty but is the best type in the area for pasture.

Orangeburg Soils.

The group characteristics of these soils are described on page 14,

Orangeburg fine sand is a brownish red to grayish red fine to medium sandy loam 2 feet deep with a red and sometimes yellowish clay subsoil. It is found on ridges and hill tops, has good drainage, is easily worked, retains moisture well, and is largely under cultivation. The soil is adapted to cotton, corn, tomatoes, water melons and cantaloupes.

Orangeburg clay is a heavy red sandy loam or red clay loam 15 inches deep with a red sandy clay subsoil. It is found on crests of ridges, slopes of hills and on large rolling areas. It is mostly well drained, but in some of the level areas the soil is so impervious to water that little is absorbed, and the soil is very unproductive. Cotton, corn, and sorghum are grown, and are fairly productve, but the soil is droughtly.

* A description and map of the soils of this area is published by the Bureau of Soils as "Soil Survey of the San Antonio Area, Texas' by Thos. A. Caine and W. S. Lyman. (Advance sheets—Field Operations of the Bureau of Soils, 1904).

Other Soils.

Portsmouth sandy loam is a bluish gray to dark colored sandy loam of fine to medium texture 18 inches deep, with a similar subsoil. In dry weather it becomes so hard and compact that it cannot be cultivated, in wet weather it absorbs moisture well.. The local name is black sand. The surface is rolling, the drainage good, but little is under cultivation, owing to the expense of clearing away the dense growth of mesquite which it supports.

San Antonio clay loam is a brownish or chocolate colored loam or clay loam 8 to 12 inches deep, with a similar subsoil, which becomes gradually lighter in color. Large areas are under irrigation. It is very productive, and used for cotton, corn, sorghum, alfalfa, and truck. It endures drought well.

Austin fine sandy loam is a brownish-yellow or reddish-gray colored fine sandy loam, with a similar subsoil, which becomes gradually lighter in color, known locally as "shelly land". This is a level soil, drainage good, a good soil, but inclined to be droughty. Cotton, corn, fruit, vegetables, and alfalfa are grown.

Table 18.—Percentage Composition of Bexar County Soils.

	Norfolk Sand	Norfolk Silt Loam	Houston Black Loam	Houston Black Clay	Orangeburg Fine Sand	Orangeburg Clay	Portsmouth Sandy Loam	San Antonio Clay Loam	Austin Fine Sands Loam
	Surface Soil	Surface Soil	Surface Soil	Surface Soil	Surface Soil	Surface Soil	Surface Soil	Surface Soil	Surf. Soil
Phosphoric acid..	.02	.02	.06	.08	.02	.09	.03	.08	.11
Nitrogen	.04	.09	.18	.12	.05	.11	.08	.08	.11
Potash	.05	.17	.80	.32	.25	.45	.23	.47	.03
Lime	.04	.05	3.06	1.16	.18	.35	3.40	8.06	23.64
Magnesia	.02	.14	.73	1.83	.01	.35	.37	4.01	.62
Carbon Dioxide..	.02	.11	1.31		.01	.02	2.60	5.23	
Sulphur Trioxide	.06	.03	.06		.02			.07	
Alumnia and ...	.31	1.70	8.05	11.40	2.56	11.43	6.88	5.83	4.29
Oxide of Iron ..	.27	.86	.96					1.78	
Insoluble and Soluble Silicia..	97.95	92.08	70.77	72.93	95.06	77.33	79.08	57.96	39.96
Loss on Ignition.	1.12	3.12	6.31	6.41	1.40	6.21	5.76	10.89	11.10
Moisture	.24	1.94	6.85	6.70	.56	2.90	2.80	5.67	1.55

Table 19.—Interpretation of Analyses.

	Orangeburg fine sand	Orangeb'g clay	Portsmouth sandy loam	San Antonio clay loam	Austin fine sandy loam
Phosphoric acid	Low	Fair	Low	Good	Good
Nitrogen	Low	Fair	Fair	Fair	Good
Potash	Good	Fair	Good	Good	Low
Lime	Abundant	Fair	Abundant	Abundant	Abundant
Depth of Soil	24"	15"	18"	8 1-2"	2
Yield of Cotton	½-1	—	—	½-¾	½-1 B.
Yield of Corn	35	—	—	35	35 bu.
Local opinion	Productive	Droughty Partly productive	Little Cultivated	Productive	Productive

	Norfolk sand	Norfolk silt loam	Houston black loam	Houston black clay
Phosphoric Acid	Low	Low	Good	Good
Nitrogen	Low	Fair	Very good	Good
Potash	Low	Sufficient	Good	Good
Lime	Low	Low	Abundant	Abundant
Depth of Soil	10"	6-8"	8-15"	7"
Yield of Cotton	—	—	2-3	1 ....
Yield of Corn	—	—	30	50 bu.
Local opinion	Not utilized (droughty)	Not desirable (droughty)	Productive	Droughty

COMPOSITION OF BEXAR COUNTY SOILS.

Table 18 contains the chemical analyses made of the soils of this area and Table 19 the interpretation of the same. Moisture conditions are very important in this area.

Phosphoric acid is low in the Norfolk sand, Norfolk silt loam, Orange-fine sand and Portsmouth sandy loam.

Nitrogen is low in the Norfolk sand and Orangeburg fine sand. The other soils contain a fair amount.

Potash is low in the Norfolk sand and Austin fine sandy loam.

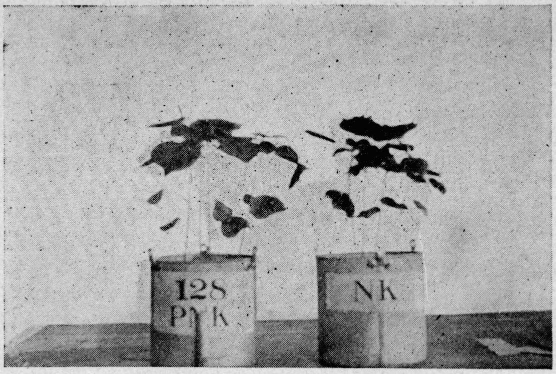
Lime is low in the Norfolk sand and Norfolk silt loam. The other soils contain an abundance of lime.

POT EXPERIMENTS.

The results of the pot experiments are presented in Table 19. The San Antonio clay loam appears to be deficient in potash. All the soils tested appear to respond to applications of phosphoric acid fertilizers.

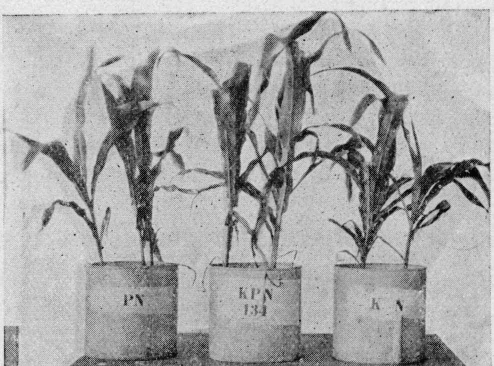
Table 20. Pot Experiments with Bexar County Soils.

Laboratory Number	Crop per pot NK Gm	PNK Gm	PN Gm
135 Norfolk sand (cotton)	15.3	18.2	19.3
128 Norfolk silt loam (cotton)	3.1	4.9	4.2
127 Houston black clay (corn)	6.9	12.0	12.2
131 Orangeburg fine sand (corn)	3.1	14.1	
134 San Antonio clay loam (corn)	6.6	9.5	6.9



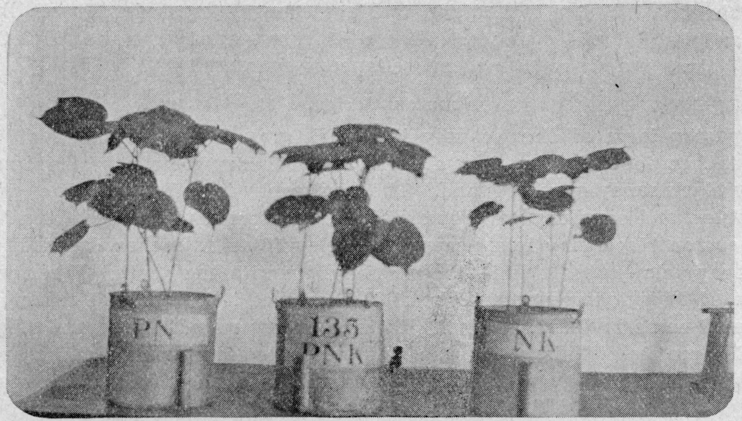
Norfolk Silt Loam.

Houston Black Clay.

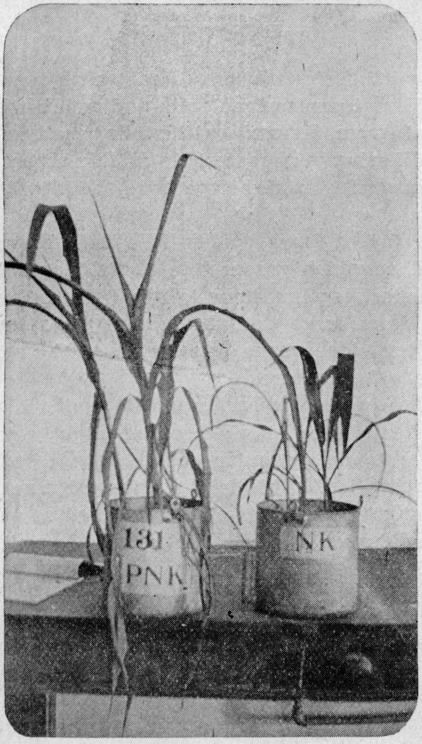


San Antonio Clay Loam

An application of phosphoric acid is denoted by P., Potash by K, and nitrogen by N.



Norfolk Sand.



Orangeburg Fine Sand.

SOILS OF HAYS COUNTY.*

This area includes in addition to Hays county, parts of Caldwell, Bastrop, and Guadaloupe counties. The soils represented are the Houston series (black prairie soils) and miscellaneous soils.

Houston Series.

Houston loam of Hays county is a dark gray to light brown loam 10 to 12 inches deep, grading into a dark-drab to heavy loam subsoil, termed locally black sandy or mixed land. The topography is rolling. Cotton, corn, vegetables, and sorghum are grown, especially sweet potatoes and tomatoes.

Houston black clay is a heavy black clay 10 to 12 inches deep with a stiff, heavy clay subsoil, which becomes lighter with the depth. When well cultivated it is loamy and friable, and when wet it is stiff and tenacious. The local name is "'black waxy." It occupies low rounded hills and ridges and also prairies. This soil is the most valuable farming soil in the area, being productive and durable. It is adapted to cotton, corn, and forage crops.

Houston clay is a dark brown to black clay 10 to 12 inches deep with a stiff heavy drab clay subsoil gradually changing to chalky limestone. The soil is well drained, with rolling surface. This land is used for pasture, and cotton, corn, sorghum, and potatoes are grown. The soil suffers during drought.

Crawford Series.

These are residual limestone soils of the prairie regions, characterized by dark loam to reddish loam surface soils and reddish brown to red subsoils. While derived from limestones, the soils usually contain only a small percentage of lime, differing very materially in this repect from the soils of the Houston series, occurring in the cretaceous black prairies of the coastal plain.

Crawford stony clay of Hays county is a dark loam to reddish loam clay 8 to 10 inches deep which grades into a stiff clay subsoil of a slightly redder color. The underlying limestone is 2 to 4 feet below the surface. The proportion of stones is so large that the land is unfit for agricultural purposes, though when the stones have been removed the soil is very productive. It is used chiefly for pasture.

Crawford Silt Clay is a brown to reddish brown clay loam 10 to 12 inches deep with a heavy silty clay subsoil of slightly redder color. This soil breaks up into a loamy granular condition, and is easily put into a thorough state of cultivation. This is the principal truck soil of the area, onions principally being grown. It is also considered as an excellent soil for general farming; corn, cotton, peanuts, and alfalfa do well.

* A description and map of the soils of this area is published by the Bureau of Soils of the U. S. Department of Agriculture "Soils Survey of the San Marcos Area, Texas" by A. W. Mangum and W. S. Lyman (Advance Sheets, Field Operations of the Burean of Soils, 1906.)

Other Soils.

Blanco loam is a heavy gray loam or silt loam 10 inches deep with a light brown heavy silt loam subsoil. When wet or recently cultivated the surface appears brown. The soil is well adapted to general farm crops and vegetables, but occurs only in limited areas. Cotton, corn, Irish potatoes, and alfalfa do well.

Susquehanna fine sandy loam is a gray to light brown fine sandy loam 10 to 15 inches deep with a stiff impervious clay subsoil dark red to brown in color. The soil is easily cultvated but runs together after heavy rains becoming very compact. This soil is not as productive as the black prairie land, but is adapted to a greater variety of crops. It is especially adapted tc watermelons, sweet potatoes, and peanuts. It is also well adapted to fruits, such as peaches, plums, and blackberries. Cowpeas do well and benefit the land when ploughed under. Cotton is also grown.

Wabash clay is a heavy black clay 10 inches deep with a stiff tenacious clay subsoil. It is an alluvial soil, subject to inundation, and is very productve. It is especially adapted to corn; sorghum and cotton are also grown.

TABLE 21—PERCENTAGE COMPOSITION OF HAYS COUNTY SOILS.

	Houston Loam		Houston Black Clay		Houston Clay		Crawford Stony Clay		Crawford Silt Clay		Blanco Loam		Susquehana Fine Sandy Loam		Wabash Clay	
	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	Subsoil	Surface Soil	
Phosphoric Acid	.01	...	.08	.06	.09	.10	.18	.11	.10	.33	.12	.10	.04	.04	.15	.....
Nitrogen	.18	.....	.13	.06	.28	10	.20	.28	.18	.09	.11	.07	.09	05	.13	.....
Potash	.29	.....	.20	.06	.04	.03	.58	.28	.78	.81	.05	.40	.34	.43	.41	.....
Lime	.37	......	19.61	14.40	19.32	30.21	12.40	16.61	1.58	1.62	34.91	34.44	.70	.62	9.86	.....
Magnesia	.23	......	.62	.22	.44	.45	.30	02	.83	.24	.91	.48	.20	1.27	.96	.....
Carbon Dioxide	.09	......	.....	......	.....	...	.....	.. ..	......	.....	.....	.....	......	... ..	.....	.....
Sulphur Trioxide	.05	......	......	.02	.07	......	.10	.. ...	.03	....	.13	.10	....	....	....	.....
Alumina and Oxide of Iron	6.23	.....	9.74	12.64	12.17	8.27	16.01	15.60	15.00	15.54	5.76	5.30	15 12	14.40	52.56	.....
Insoluble and Soluble Silicia	85.24	......	42.07	48.91	38.75	26.90	45.09	41 75	63.19	62.81	23 61	22 44	72.39	73.38	9.98	.....
Loss on Ignition	4.35	...	.....	7.62	9.75	8.69	12.00	13.44	7.44	9 79	12.20	7.73	5.20	.....	7.72	. ...
Moisture	2.32	......	......	7.01	5.30	5.00	6.12	6.61	8.45	8.59	2.75	2.51	5.35	.....	5.65	. ...

CHEMICAL COMPOSITION OF HAYS COUNTY SOILS.

Table 21 contains the chemical analyses of the soils of Hays county, and Table 22 the interpretation of the results.

Phosphoric acid is low in the Houston loam and Susquehanna fine sandy loam.

Nitrogen appears to be fair in all the soils.

Potash is low in the Houston clay and Blanco loam.

There is a sufficient amount of lime in all these soils.

Table 21—Interpretation of Analyses of Hays County Soils.

	Houston loam	Houston black clay	Houston clay	Crawford stony clay	Crawford Silt clay
Phosphoric Acid	Low	Good	Good	High	Good
Nitrogen	Good	Fair	Very Good	Very Good	Good
Potash	Fair	Fair	Low	High	Good
Lime	Good	High	High	High	Good
Depth of Soil	10-12"	10-12"	10-12"	8-10"	10_12"
Yield of cotton (bales)	0.3 ½	¾-1	¼-0.3	¼-0.3	1
Yield of corn	18.25	35	20-25	15-20	35-40 bu.
Local Opinion	Fair Soil	Productive and durable	Droughty	Too Stony	Productive

	Blanco Loam	Susquehanna Fine Sandy loam	Yazoo clay
Phosphoric Acid	Good	Low	Good
Nitrogen	Good	Fair	Good
Potash	Low	Good	Fair
Lime	High	Sufficient	High
Depth of Soil	10"	10-15"	10"
Yield of Cotton (Bales)	½-¾	0.3	0.3 to 1.
Yield of Corn (Bushels)	25-35	15-20	40-50
Local opinion	Good	Good	Productive.

POT EXPERIMENTS.

Table 22 shows the results of the pot experiments on these soils.

The Houston clay and Susquehanna fine sandy loam appear to respond to fertilization with potash.

All the soils tested appear to respond to nitrogenous fertilizer.

They all appear to respond to applications of phosphatic fertilizer. The Crawford stony clay is least responsive in this respect.

Table 22—Pot Experiments with Hays County Soils.

Laboratory number		Crop per pot KN	PNK	PN	PK
334	Houston loam (corn)	8.5	30.1	28.8	16.0
324	Houston black clay (corn)	6.4	16.1	12.8	10.2
330	Crawford stony clay (corn)	15.0	19.8	17.0	10.1
336	Susquehanna fine sandy loam (corn)	2.1	20.1	12.0	7.5
338	Wabash clay (corn)	7.1	12.0	15.1	7.0

Houston Loam

Crawford Stony Clay

Susquehanna fine sandy loam

Wabash Clay

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Summary and Conclusions.

1. Chemical analyses and pot experiments are here reported. Typical samples of Texas soils, collected from Anderson, Houston, Travis, Bexar, Hays and Lamar counties were studied.

2. The plant food in the soil is an important factor in crop production, and is subject to control by the tiller of the soil, though there are other factors equally important.

3. A fertile soil supplies active plant food; that is plant food in such forms that the plant can take it up. The amount of active plant food in a given soil depends upon the nature of the soil and the treatment to which it has been subjected.

4. The physical and chemical causes of low crop yields are discussed. The chemical causes are acidity, alkali, and deficiency in active plant food, in active lime, and in organic matter.

5. In maintaining soil fertility, the losses of organic matter should be restored, a sufficient supply of active lime must be maintained, and a sufficient quantity of active phosphoric acid, potash, and nitrogen must be kept in the soil.

6. The losses of active plant food may be restored by application of manure, and by use of commercial fertilizers.

7. Every farmer should grow leguminous crops, such as alfalfa, cowpeas, peanuts, etc., as much as possible, for his own use, for sale, and for ploughing under. In this way nitrogen is secured from the air and utilized.

8. The chemical analysis of a soil must be considered in connection with other facts which influence its fertility. Chemical analysis with strong acids gives information in regard to the strength and wearing qualities of the soil, and is of more permanent value than estimation of the active plant food, because the amount of the latter may change from year to year.

9. Pot experiments give information in regard to the immediate needs of the soil for plant food.

10. The chemical composition of samples of the same type from widely separated areas are strikingly similar in the soils we have examined.

11. The soil series appear to have definite chemical characteristics, though some variation is observed. The productiveness of the soils is related to the chemical composition.

12. The average quantity of plant food in each series of soils, and the number of crops of cotton and corn that may be produced with this quantity, is given in the tables. Since nitrogen is washed from the soil, as well as taken up by the crop, the store of nitrogen would be exhausted first, the phosphoric acid next, and the potash last of all.

13. A description and a chemical analyses is given of the soils of Anderson, Houston, Hays, Lamar, Bexar, and Travis counties. Interpretation of the analysis is made for each soil examined.

14. Pot experiments were made on a number of soils to test the immediate needs of the soils for phosphoric acid, potash, and nitrogen. The Texas soils which we have tested respond to phosphoric acid in almost all cases, very often to nitrogen, and not very often to potash.

15. As a general rule, the soils of Texas respond to phosphoric acid fertilizers most, next to nitrogen, and least of all to potash.