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1947

# The Cation Exchange Capacity of the Soils of the Tennessee Agricultural and Industrial State College Farm

Fred E. Westbrooks

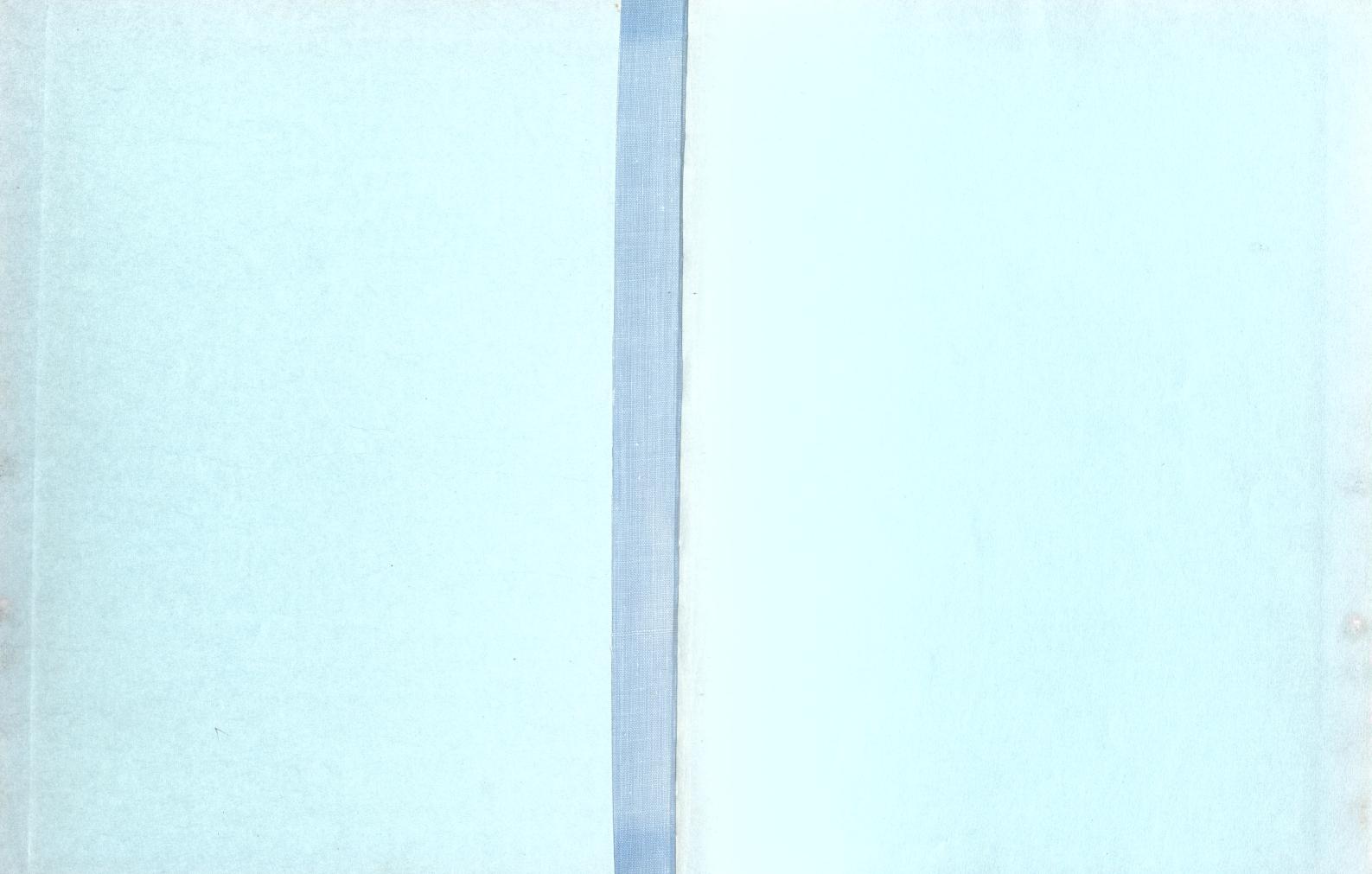
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THE CATION EXCHANGE CAPACITY
OF THE SOILS OF THE TENNESSEE
AGRICULTURAL AND INDUSTRIAL
STATE COLLEGE FARM
BY
FRED E. WESTBROCKS

TENNESSEE A. & I. STATE COLLEGE



August 22, 1947

To The Committee On Graduate Study:

I am submitting to you a thesis written by Fred E. Westbrooks, entitled "The Cation Exchange Capacity of the Soils of the Tennessee Agricultural and Industrial State College Farm." I recommend that it be accepted for nine quarter hours credit in partial fulfilment of the requirements for the degree of Master of Science with a major in Agronomy.

We have read this thesis and recommend its acceptance:

Accepted for the Committee

ueust 22. 1947

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U. Hel Sheeter

Accepted for the Committee

Director of the Granate Bivision

THE CATION EXCHANGE CAPACITY OF THE SOILS

OF THE

TENNESSEE AGRICULTURAL AND INDUSTRIAL STATE COLLEGE FARM

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A THESIS

Submitted to

The Committee on Graduate Study

of

Tennessee Agricultural and Industrial State College

in

Partial Fulfilment of the Requirements

for the degree of

Master of Science

Fred E. Westbrooks

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August, 1947

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DEDICATION
Epacial shaper are also given to Me. D. H. Horg. For a Communication

To my father and mother, Mr. Atha Westbrooks and the late
Mrs. Albertha Westbrooks, whose greatest ambition was and still
is that I succeed in making a contribution to civilization.

iii

#### MOTTAGIGEG

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## ACKNOWLEDGMENT

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Special thanks are also given to Mr. D. H. Esry, Soil Conservationist, and Mr. C. B. Brenig, assistant Soil Conservationist, for work done in connection with Figure 3 of this work.

Appreciation is expressed to other members of the Agricultural Staff for helpful criticism and suggestions.

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# INTRODUCTION

The Tennessee Agricultural and Industrial State College campus and farm is composed of 320 acres of land, located just out of the city limits of North Nashville, on the Cumberland River. This farm varies from very good farm land to a small section too stony to cultivate.

During the month of February the district soil conservationist, Mr. D. H. Esry and his assistant, Mr. C. B. Brenig, along with a class of four students, under the supervision of Dr. M. F. Spaulding, made a detailed survey of the college farm.

This survey resulted in the finding of seven different soils found in different localities of the farm, and having varying degrees of slope and erosion.

The author, a member of the class of four in Soil Classification, became interested in going a step farther into the analysis of these soils; to the extent that recommendations could be made as to the liming, and fertilizing practices to be carried out on this farm.

As a basis for making the said recommendation the Cation Exchange Capacity or the Adsorptive Capacity of each type of soil found on the farm was made.

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The minute and seterogeneously despersed clay particles are electrically active, (4) ordinarily carrying a considerable electrical potential. This is one to an icute double layer phenomenon. The inner layer is an immovable stratum of negatively charged ions (amons) that are an integral part of the surfaces, both severnal and internal, of the colloidal particles. The outer layer is made up of certain particles in care, at later in part, readily displaced (Fig. 1).

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Way, in 1850 (9) was the first to explain soil absorption on the chemical basis: that is, calcium and ammonium (NH<sub>4</sub>) for example, exchanged places according to chemical reaction. Liebig held the view that absorption was physical like the absorption of gases by charcoal. Since 1861, when Graham (Eng.) introduced the term "colloids" and so shaped the concept regarding them as to make possible scientific inquiry into their nature, absorption research in soil science has centered on colloidal soil materials. Van Bemmelen Hall, 1878, was the first investigator to observe the colloidal properties of the clay and humus of soil. At first, he accepted Way's chemical hypothesis of absorption, but later in 1890 he concluded that displaceable basic elements were held in soils by adsorption, that is, on the surfaces of colloidal particles.

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Thus, as the clay particle moves through its dispersive medium it is accompanied by a swarm of cations, and the farther away the more active members of this pulsating throng maintain themselves, the greater is the electrical potential of the particle. Since the charges on the particle itself are normally negative, it functions much like a simple acid radical such as Cl- or SO<sub>4</sub>=, and will migrate to the positive pole when subjected to an electrical current.

For convenience in designation the individual particle is spoken of as an Acidoid, a Micelle or a Nucleus.

It is now evident that the micalike clay particles are composed of two distinct parts: the inner porous, and enormously larger insoluble acidoid or micelle, and the outer and more or less dissociated swarm of cations with variable amounts of water of hydration. Since these adsorbed cations are usually rather easily displaced, they are spoken of as exchangable ions. This replacement, called ionic exchange or cation exchange or more commonly base exchange, is one of the most important of all soil phenomena. (figure 1)

While all sorts of cations may thus be loosely held by the adsorptive power of the clay nuclei, certain ones are especially prominent (Figure 2). For a humid-region clay, these in the order of their numbers are H+ and Ca+ +, first; Mg+ +, second; and K+ and Na+, third. For well drained arid-region soil, the order of the exchangable ions is Ca+ + and Mg+ +, first; Na+ and K+, next; and H+ least.

Two general types of atomic sheets (4) constitute the individual units or molecules that build up the complicated clay particles. One is

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Two groups of clays are commonly recognized (4,8,11): the kaolin and the montmorillonite. The molecule of the former are thought to be composed of two sheets or plates, one of silica and one of alumina. Such clays are therefore said to have a 1 to 1 type of crystal lattice. Since the molecules are apparently held together rather tightly, the internal interface is much restricted. Therefore, the two representations of the kaolin group, kaolinite and halloysite, do not exhibit colloidal properties of an unusual high order.

The second general group of clays, the montmorillonite, apparently is composed molecularly of two silica sheets and one of alumina. It
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An unusually large amount of internal interface is thus exposed and molecules of water and the cation of various substances may force themselves between the sheet like molecules. As a result adsorption is more marked than in the case of kaolin clays, and other colloidal properties, such as plasticity, cohesion, and especially base exchange, are greatly in evidence.

Hendricks and Alexander (3) states that while all of the clay minerals show cation exchange, montmorillonite has considerably the greater capacity, which is of the order of 1.0 M. E. per gram. The value for the micalike mineral is about 0.2 M. E. per gram, and that for kaolinite is less than 0.1 M. E. per gram. Although these quantities do not vary greatly they are not sufficiently constant to serve as more than a rough check of mineral composition. Each mineral, however, differs in the order of ionic replacement at equivalent concentrations. The availability of the sites for cation exchange, furthermore, show a different dependence upon ionic size for the several minerals. The nature of the exchange site also influences the manner in which the cation hydrates.

The importance of the Cation Exchange Capacity of a soil cannot be easily overestimated. Lyon and Buckman (4) recognizes Marshall's
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It is probable that higher plants, possibly by contact replacement, can make ready use of at least a part of the exchangable constituents of soils. The nutritional importance of base exchange is therefore undoubted.

The cation exchange capacity, or the base exchange, or ionic exchange capacity, as it is often called, according to results of investigations, (9) may be defined as the displacement of basic elements (including Hydrogen) that are chemically combined insoluble soil compounds by other basic ions and hydrogen when soil materials are brought in contact with salt, base, and acid solutions. These cations are governed by the chemical "electromotive series" and "mass action." An example of this is sodium (Na+) easily replaced by Calcium (Ca++), Calcium by hydrogen (H+) and ammonium ions (NH<sub>4</sub>+).

Cation Exchange (9,12) is recognized as a most important fundamental or principle of soils. In it are found explanations for several important soil phenomena or conditions including soil acidity and alkalinity, friability of some clays, fixation of Potassium (K+) and Ammonium (NH<sub>L+</sub>), and non fixation of nitrate nitrogen NO<sub>3</sub>-).

To the inquiring mind a question immediately arises. What is the magnitude of this all important property, or in technical terms, what is the exchange capacity of silicate clays or soils?

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another term for the relative adsorptive power of a clay; the method of expressing its magnitude must be explained. The unit is a milli-equivalent (M.E.) and it is defined as "one milligram of hydrogen or the amount of any other ion that combines with or displaces it." Milliequivalents, when applied to soils are usually expressed on the basis of 100 grams of dry substance (4).

Thus if a clay has a total exchange capacity of one milliequivalent it is capable of adsorbing and holding one milligram of hydrogen (H+) or its equivalent for every 100 grams of dry substance.

As might be expected, the exchange capacity of soil clays exhibit a wide range since a number of different clay minerals are always present and their proportionate amounts markedly vary with conditions of climate and soil material. Lyon and Buckman (4) states that in clays extracted from Iowa soils, the exchange capacities of montmorillonite hydrous mica and kaolin were in the order of 100, 30, and 10 milliequivalents respectively.

It is thus easy to see why the clay complex of southern soils, dominated as they are by kaolin minerals should have a low exchange capacity ranging perhaps between 20 and 30 milliequivalents. On the other hand the clays functioning in the soils of the middle west where hydrous mica and montmorillonite are prominent have a much higher base exchange capacity ranging from 50 to possibly 100 milliequivalents, depending on the conditions.

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ing. Clays differ markly in their base exchange properties. Hence, soils also will differ widely in this all important capacity, not only because they possess different amounts of clays but also because the clay is a fertility factor of tremendous importance.

The cation exchange capacity deals primarily with the colloidal material in soils. There are two types of colloidal material in the soil (6,4): namely, mineral and organic. In some ways their influences are similar, in other respects, decidedly antagonistic.

The mineral colloid is made up of complex silicates normally gellike in character, and highly plastic and cohesive. The residues is low in plasticity and cohesion. Both types of colloidal matter, however, have high adsorption, are markedly dynamic, and are active catalytic agents.

The lack of inorganic colloidal matter in sandy soils has certain obvious advantages (4,10): looseness, friability, good aeration and drainage, and easy tillage. By the same token the lack of inorganic colloidal matter in sandy soils has certain obvious disadvantages: excessive drainage and excess aeration.

One of the outstanding characteristics of the colloidal complexes of the soil both mineral and organic is the capacity of adsorbing cations. Rich and Obenshain (6) presents data to show that: 1. There is a close relationship between the cation exchange capacity and the organic content of the soils studied. As the organic matter present increased, the milliequivalent increased. They also found that ferti-

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lizer and crop practices which tended to increase crop yields also tended to increase soil organic matter and cation exchange capacity. 2. There was a significant positive correlation between organic matter content and cation exchange capacity of the soil. The organic fraction seemed to be of greater importance than the mineral fraction in contributing to the cation exchange capacity of this soil. 3. Where farm manure was applied, exchangeable calcium, magnesium potatium, and cation exchange capacity were increased significantly.

Whitt and Baver (12) found that when the milliequivalent of exchangeable hydrogen per 100 grams are plotted as a function of the average diameters of the particles the exchange capacity increases with decreasing particle size. This increase in exchange capacity is usually considered as being due to an increase in the surface per gram and hence to a greater number of exchange points per unit weight of material.

There are several methods of determining the cation exchange capacity of a soil. Bower and Truog (2) found that the results for cation exchange capacity of montmorillonite and Miami clays when determined by means of the monovalent cations, sodium (Na+), potassium (K+), Hydrogen (H+), and Ammonium (NH++) are in good agreement with the results obtained by titration curve method. When the exchange capacity results for the divalent cations are compared, it is noted that the cations which form the weakest base give the highest values. The stronger base forming cations, barium (Ba++) and strontium (Sr++) give re-

sults only very slightly higher than the true exchange capacity. While weaker base forming cations, calcium (Ca+ +), magnesium (Mg), and manganese give much higher results. Since monovalent cations do not give high results for exchange capacity, the values obtained by means of ammonium (NH4) represents the true exchange capacities of the clays.

Sieling (7) states that a knowledge of base exchange capacity of soils is of considerable help in diagnosing lime and fertilizer needs.

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Fig.1 Diagrammatic representation of colloidal clay crystal with its lamellar nucleus or micelle. its innumerable negative charges, and its swarm of exchangeable cation. Under the influence of an electric current such a particle will move toward the positive electrode.

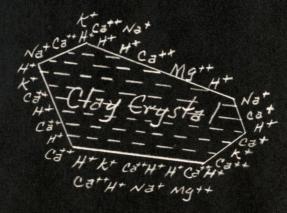


Fig.2 Diagram of a clay crystal showing the various cation that usually occupy the exchange complex. Note that Ca and H ions are dominant. No attempt has been made to indicate the numerous adsorbed molecules of water.

Tr. L. Lyon and H. O. Buckman, The Nature and Properties of Soils, pp. 70-71.

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## METHODS AND MATERIALS

A composite sample was taken from each plot labeled: 10-Huntington, 21-Maury, 40-Lindside, 42-Dickson, 61-Maury, 81-Dunning, and
83-Melvin, irrespective to the slope and the degree of erosion. A
two inch soil auger was used in securing the samples. A minimum of
six borings was made in each plot. The sample was taken from the
first one to six inches of the top soil. The respective samples
were mixed thoroughly and placed in the agronomy laboratory to air dry.

After the soil had completely air dried, it was put on a table in the agronomy laboratory and well pulverized in preparation for the analysis.

#### ANALYSIS

The determination of the moisture content was done as follows:(1)

the total cation exchange capacity of the soil.

- 1. Weigh 2 grams of soil in crucible.
- 2. Place in oven at 105 degrees C for 5 hours.
- 3. Cool in desiccator and weigh.
- 4. Calculate results.

The determination of the organic matter content was done as follows: (1)

- Take soil and crucible from the determination of moisture content.
- 2. Place crucible with soil in muffle furnace at 600 degrees C for 1 hour.
- 3. Cool in desiccator and weigh.
- 4. Calculate the results.

The determination of the cation exchange capacity was done as follows: (5)

1. Saturate 50 grams of soil sample with 250cc of N Ammonium acetate solution PH 7.0. Stir well and allow to stand over night at room temperature.

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The determination of the cation exchange capacity was done as follows: (5)

1. Saturate 50 grams of soil sample with 250cc of N Ammonium acetate solution PH 7.0. Stir well and allow to stand over night at room temperature.

2. Filter through a 15 cm Whatman No. 44 filter paper and leach with further portions of Ammonium Acetate, allowing one portion to leach completely before repeating.

peating.

3. Wash the soil repeatedly with 60% alcohol until the excess of ammonium acetate is removed. (This may be done by adding a small quantity of Ammonium chloride to the first lot of alcohol used for washing and then leaching with alcohol until the filtrate gives no test for chloride. When free from chloride discard the alcohol washings).

4. Then remove the adsorbed ammonium by washing once with 0.1 N Potassium sulfate and continuing with N Potassium Sulfate, until one litre of filtrate has been collected.

5. Transfer an aliquot of the filtrate to a litre Erlenmeyer flask. Add 2-3 grams of magnesia and distil the ammonia into a measured amount of 0.05N hydrochloric acid.

6. Titrate the excess of hydrochloric acid with 0.05N sodium hydroxide using methyl red as indicator.

7. The total amount of ammonia adsorbed by the soil and displaced by the potassium sulfate corresponds to the total cation exchange capacity of the soil.

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Soil number 10 (figure3) is classified as being a well drained brown first bottom Huntington soil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February, 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 1

Moisture Content

No. of Sample		Wt. of Soil before heating	Wt. loss' on heat '	% of Moisture
1	1	2.0196g	.0446g !	2.20
_ 2	1	2.0900g	.0462g !	2.21
_ 3	1	2.0920g	.0468 0 1	2.23
Ave.&der	V. 1		1	2.21 ± .01

Table 2

Organic Matter Content

No. of Sample	'Original 'of sample		Wt. loss on heating		% of organic matter
1	1 2.0196g	1	.1024g	1	5.07
2	1 2.0900g	t	.1046g	1	5.00
3	1 2.0920g	1	.1050g	1	5.02
Ave.& de	ev!	1		1	5.03+03

Table 3

#### Cation exchange capacity

No.of sample	1	M. E. per 100g soil
1	t.	29.85
2		29.00
3	1	30.00
Ave. & dev.	1	29.62 ± .41

- 2. Filter through a 15 cm Whatman No. 44 filter paper and leach with further portions of Ammonium Acetate, allowing one portion to leach completely before repeating.
- 3. Wash the soil repeatedly with 60% alcohol until the excess of ammonium acetate is removed. (This may be done by adding a small quantity of ammonium chloride to the first lot of alcohol used for washing and then leaching with alcohol until the filtrate gives no test for chloride. When free from chloride discard the alcohol washings).
- . Then remove the adsorbed ammonium by washing once with 0.1 N Potassium sulfate and continuing with N Potassium Sqlfate, until one litre of filtrate has been collected.
- Transfer an aliquot of the filtrate to a litre Erlenmeyer flask. Add 2-3 grams of magnesia and distil the
  ammonia into a measured amount of 0.05% hydrochloric
  - Titrate the excess of hydrochloric acid with 0.05W
- sodium hydroxide using methyl red as indicator.

  7. The total amount of ammonia adsorbed by the soil and displaced by the potassium sulfate corresponds to the total cation exchange capacity of the soil.

#### RESULTS

Soil number 10 (figure3) is classified as being a well drained town first bottom Huntington soil. This classification was gived by the district soil conservation department located in Mashville, lennessee, February, 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

	'ssol .Juss'	Wt. of Soil	1 10.00
erudatoli	1 Jean no	before heating!	' signal
2.20	1 50440.	2.0196g	t f
2.21	1 12 80,40.	2.0900g	1 5
2.23	. 0468 - 1	2.0920g	1
10. ± 19.9	1	1	.vebs.eva

We will			-		July 2	
M 250	12 M I	300	100	UMIL		Organ

Table 2

10 8 '	Wt. loss	1	'Original wi	20 .0
organic matter		1	'elqmse lo'	elqms
1 5.07	9 ASO1.	1	1 2.0196g	
1 5.00	adaoi.	1	1 2.09002	2 1
5.02	.1050g	1	2.0920.2	
1 5,03 - 103		1	!v:	ab &. evA

Cation exchange capacity

[able

M. E. per 100g soil	
29.85	1 1
00.08	1 2 2
30.00	
14. 4 50.92	Ave. & dev.

Soil number 21 (Figure 3) is classified as being a brown blue grass Maury soil, with permeable subsoil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 4

Moisture Content

No. of	'Wt.of soil	1	Wt. loss	10	% of
sample	before heat	1	on heat		moisture
1	! 2.0002g	1	.0528g	1	2.64
2	! 2.0004g	1	.0530g	1	2.65
3	1 2.0008g	1	.0533g	1	2.66
Ave. & d	ev!	1		1	2.65 ± .06

Table 5

Organic Matter Content

No. of 'sample'	Original wt. of sample	Wt. loss on heating	1	% of Organic Matter	1
1 '	2.0002g	.11610	1	5.80	1
2 !	2.0004g 1	.1165g	1	5.82	1
3 1	2.0008g !	.1158g	1	5.79	1
Ave. & dev!	1		1	5.80 +01	1

Table 6

Cation exchange capacity

No. of sample	M.E. per 100g soil
1	22.02
2	21.87
3	21.86
Ave. & dev.	21.92+07

Scil number 21 (Figure 3) is classified as being a brown blue grass Maury soil, with permeable subsoil. This classification was given by the district soil conservation department located in Mashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Moisture Content

Table 4

io . 0.	Ilos lo.J.	Wt. loss	10 % of
emple	designe nest	Jaen no	1 moisture
L	1 2.0002g	.0528g	2.64
2	1 2.00048	.0530a	2.65
3	1 2.0008g	n8880.	2.66 -
ob & .ov.	! v		80. = 88.8

Organic Matter Content

Table 5

lo &	1 seof .JW	'.Jw Isnigiro '	10.00
Organic Mabter	on heating !	' elemsa lo '	sample
5.80	.11610	1 2.0002g 1	I
5.82	.11.65@	1 2.00040 1	2
5.79	11588	1 2.00082 1	3.1
ro+ 08.2	1	ı lv	ob & .evA

Cation exchange capacity

Table 6

M.E. per 100g soil	lo. of sample
22.02	I
78.12	200
21.86	
70150.15	ve. & dev.

Soil number 40 (Figure 3) is classified as being a medium drained first bottom Lindside soil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 7.

Moisture Content

•	Wt. of soil	1	Wt. Loss	1	% of	1
1	before heating	1	heating	1	moisture	1
1	2.0010g	1	.0549g	1	2.74	1
1	2.0006g	1		1	Market and the second s	
1	2.0030g	1		1	2.79	1
1	The state of the s	1		1	2.76+=.0	21
	1 1 1	before heating 2.0010g 2.0006g 2.0030g	before heating ! 2.0010g ! 2.0006g ! 2.0030g !	before heating ' heating ' 2.0010g ' .0549g ' 2.0006g ' .0550g ' 2.0030g ' .0560g	before heating ' heating ' ' 2.0010g ' .0549g ' ' 2.0006g ' .0550g ' ' 2.0030g ' .0560g '	before heating   heating   moisture   2.0010g   .0549g   2.74   2.0006g   .0550g   2.75   2.0030g   .0560g   2.79

Table 8

Organic Matter Content

No. of	•	Original wt.	1	Wt. loss	1	% of
sample	1	of soil	1	heating	1	Organic Matter
olof	1	2.0010 g	1	.1219 g	1	6.09
2	1	2.0006 g	1	.1218 g	1	6.08
3	1	2.0030 g	1	.1222 g	and the same	6.10
Ave. & dev	. 1		1		1	6.09+01

Table 9

Cation Exchange Capacity

No. of sample	1	M.E. per 100g of soil
1		37.97
2	annound income	37.69
3	the state of the state of	37. 78
Ave. & Dev.	un mus d'appearen	37.81 ± .10

Table 12

Soil number 40 (Figure 3) is classified as being a medium drained first bottom Lindside soil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

	10 % 01	Wt. Loss	lios to .sw	1 20.01
enu,	! moist	nesting	before heating !	. alqmaa
	1 2.74	.05498	2,0010g	1
	2.75	.0550g	2,0000.5	1 9
	27.2	g0000.	2.0030g	3. 1.
SO. 4 1	1		1	l .veb & .svA

20 2	1	Beol .JW	. Jw Isniahro	1	10 .00
Organic Matter	. 1	nesting	fros io	.1	elognose
80.0	1	e PISI.	2.0010 -	1	1
6.08	1	28181.	2.0006	1	2
or.a	1	12222	2.0030 €	1	3
10 +00.0	- 1		1	1	Ave. & dev.

	Cation Exchange Capacity	Table 9
_	M.E. per 100g of soil	vo. of sample
	37.97	I
	37.69	2 (1000)
	37. 78	8
	01. ± 18.78	vel & Dev.

Soil number 51 (Figure 3) is classified am bains land to Soil number 42 (Figure 3) is classified as being a medium drained brownish gray soil with a compact layer (pan) in the subsoil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 10	before tweeting	T hauting	Moisture Co	ntent
No. of sample	Wt. of soil before heating	Wt. loss heating	% of moisture	en ar en
101 1 2 2 2 mm	2.4508g	.0520g	2.12	order (Section 2009) 1974 - Section 2009
2	2.3980g	.0510g	2.12	AND SECTIONS
_3	22.3060g	.0500g	2.14 02	

Table 11				Organic	Matter Content
No. of	'Original wt	1	Wt. loss	(1) (1) (1)	% of
sample	of soil	1	heating	1	Organic Matter
1	1 2.4508g	1	.1670g	01	6.81
2	1 2.3980g	1	.1630g	5 20 1 1	6.79
3 1000	1 2.3060g	1	.1611g	1	6.98
Ave. & dev.	1	1			6.86 ± .08

Cation exchange capacity

No. of sample	1	M. E. per 100g of soil
semile -	1	25.51
2		25.33
3	1	25.38
Ave. & dev.	1 /	25.41 ± .07
hum h Amer		~7.41 = 001

Soil number 42 (Figure 3) is classified as being a medium drained brownish gray soil with a compact layer (pan) in the subsoil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February 1947. color, parent material, and type and depth of subscil were the bases on which the classification was made.

14		saoi .jw	F	tos to .jW	10 .00
	% of moisture			before hes	eloms:
	8.18	205-20.		28.4508g	L
	2.12	.0510g		2,3980g	SI
	so tal.s	.05000		20008.9	3
ntent	ic Earter Co	Organ			Table 11
1	lo d	t saol .j	W 1 3	v Isnigino!	10.00
Hatter	Organic	eating	d 1	fins lo!	sample
1	18.0	16700		2.45088	1
,	6.79	1630g	A THE OWNER OF THE OWNER OWNER OF THE OWNER O	30898.5	<u> </u>
1	86.98	10136 .	. 1	1 2.3060g	EL MANTE
1 80.	± 88.8		1	1	Ave. & dev.
espacit	on exchange o	idsO			Table 12
	on exchange of			1 9	
		M. E. per 25.51		1 9 1	Table 12
		M. E. per		1 3	

Soil number 61 (Figure 3) is classified as being land too stony to plow, Maury Soil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 13						Moisture Content
No. of	1	Wt. of soil	1	Wt.loss	1	% of
sample	1	before heating		heating	t	moisture
1	1	2.0026g	1	.0404g	1	2.01
2	1	2.0021g	1	.0402g	1	2.01
1 4 6 6 7	1	2.0030,	1	.0410g	1	2.05
Ave. & dev.	1		1		1	2.02 ± .02

No. of sample	1	Original wt. of soil	1	Wt. loss heating	t t	% of Organic Matter
1	1	2.0026g	1	.1390g	1	6.94
2	1	2.0021g	1	.1387	1	6.93
3	1	2.0030 g	1	.1395g	1	6.97
Ave. & dev.	1		1		1	6.95 = .02 1

Table 15		Cation Exchange Capacit				
No. of	1	The second of th				
sample	1	M. E. per 100g of soil				
o It Associa	1	20.35				
2	1	20.59				
3	1	20.89				
Ave. & dev.	Landard Control of the Control of th	20.61 ± .18				

Soil number 61 (Figure 3) is classified as being land too stony to plow, Maury Soil. This classification was given by the district soil conservation department located in Mashville, Tennessee, February 1947. The color, perent material, and type and depth of subsoil were the bases on which the classification was made.

na njerija (nijerija na projek (nijer	lo & I	zaof.jw'	We. of soil	10.0
	! modeture	! hestine	before neating	elons
The second	20.5	34040.	2.0026g	1
	20.9	.0402	2.00210	1
	20.8	OALO.	2.0030	1
00	4 00 0 1	1		ve. & dev.

1 20 g	Wt. loss	' .jw fanigino '	10.00
Organic Matter	hesting 1	· Ifos to ·	eample .
1 49.0	1 30086	1 2.0026g	I
6.93	1387.	1 2.0021g	2
1 79.0	.13958	1 2.0030 8	3
90. = 30.0	1		ves & dev.

Cation Exchange Capacity	Table 15
	lo .ol
M. E. per 100g of soil	I SLUB'S
20.59	1
98.00	3
20.61 ± .18	Ave. & dev.

Soil number 81 (Figure 3) is classfied as being a dark colored wet Dunning soil. This classification was given by district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 16

Moisture Content

No. of Sample		Wt. of soil	1	Wt. loss	1	% of
Dampie		before heat	1	heating	1	moisture
		2.0012g	ţ	.0732g	1	3.65
10205		2.0081g	1	.0790g	1	3.93
3	11	2.0020	1	.0760g	1	3.79
Ave. & de	<i>r</i> . '	The state of the s	1		1	3.79 ± .09

Table 17

Organic Matter Content

No. of sample	1	Wt. original of soil	t t	Wt. loss on heat	up v	% of Org. Matter
ol ol	1	2.0012g		.1736g	1	8.68
2	1	2.0081g		11742g		8.68
3	1	2.0020g	1	.17400	•	8.69
Ave. & de	ev.	2.02000		The state of the s	1	8.68 ± .003

Table 18

Cation Exchange Capacity

No. of sample	100	M. E. per 100g of soil
12	1	23.91
2	1 1	23.96
Tre 3 dev. 14	1	24.41
Ave. & dev.	Ţ	24.09 ± .21

Soil number 81 (Figure 3) is classified as being a dark colored wet Dunning soil. This classification was given by district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

	to &	Wt. loss !	Wt. of soil '	1	io ol
	moisture	neating 1	before heat '!	1	elqms
	3.65	.0732g '	2.0012g	1	L
	3.93	1 30970.	2.0081g	1	2
	3.79	1 20070.	2.0020 -	7	8
01	3. 4 00.8	1	1	1 .V	lve. & de

lo &	Wt. loss	' Wt. original '	lo. of
Org. Matter	on heat	i from lo	eIqms:
80.8	.1736g '	2.0012	11
80.8	117420	1 2.008Le	2
8.69	.17400	1 2.0020 1	3

Cation Exchange Capacity	Cable 18
I. E. per 100g of soil	No. of sample
23.91	1
23.96	1 8
£3. A2	3
22.09 ± .21	Ave. & dev.

Soil number 83 (Figure 3) is classified as being poorly drained gray first bottom Melvin soil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February, 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 19 Moisture Content No. of ' Wt. of soil ' Wt. loss ' % of sample before heat on heat moisture : 2.0292g .0408 2.01 2.0200g .04040 2.00 2.0299 .0481g 2.37 Ave. & dev. ! 2.13 ±.16

Table 20			Organic Matter Content				
No. of sample	1	Wt. origina of sample	11	Wt. loss on heating	* 1	% of Organic	Watter
recluier 1	1	2.0292	1	.1338g	1	6.59	me ocer
2	1	2.0200g	1	.1330g	1	6.58	
d 113 400 o	1	2.0299g	1	.1340g	1	6.60	
Ave. & dev.	1		1	A STATE OF THE STA	1	PRODUCTION OF THE PARTY AND ADDRESS OF THE PARTY AND ADDRESS.	± .01

Table 21		Cation Exchange Capacity
No. of samples	1	M. E. per 100g of soil
mineral plant and	<b>加工事故机构</b> 海拔机。	39.35
2		39.21
to at 3 male again	a regularia	39.28
Ave. & dev.	1	39.28 ± .05

Soil number 83 (Figure 3) is classified as being poorly drained gray first bottom helvin soil. This classification was given by the district soil conservation department located in hashville, Tennessee, February, 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

ture Content	Mois				Table 19
	Vt. lose	1	flos to .dw	1	io .ov
moistare			before heat	1	elgmsa
fo.s	.8040.	, 1	2.02926	1.1	1, 1
00.8	1 27070.	1	200000	1	2
77 0	1 9[840.	1	2.02990	1	3
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# Soil labeled Churcher DISCUSSION As element discuss being a well

The soils of this area belong to one of the two great soil groups of the United States, known as the pedalferic group. That is, it is a soil located in the Humid region of the United States. These soils have undergone leaching and oxidation and contain an abundance of iron and aluminum.

The A. & I. State College farm is located in Middle Tennessee, in the physiographic region known as the central basin. The central basin is the most important physiographic region of Tennessee as far as fertility of the land and density of population are concerned. This region developed on soluble Ordovician limestone is a gently undulating elliptical plain lying lengthwise across the state but almost wholly within it. The area of the basin is about 5,500 square miles, and its altitude is 500 to 700 feet above sea level. The basis is extremely irregular in outline, for it is entirely surrounded by the highland rim, 400 or more feet higher.

The soil of this region belongs to the soil group of the United States known as the Maury-Hagerstown area. The soils of this
area are dominantly heavy textured consisting mainly of silt and clay,
high in mineral plant nutrients and organic matter. These soils are
medium to strongly acid in reaction. Soils of this region are expected to be of the hydrous mica clay nature with a cation exchange capacity of approximately 20 to 30 M. E. per 100 grams of soil.

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Soil labeled Number 10 (Fig. 3) is classified as being a well drained brown first bottom Huntington soil. It appears in four different plots on the farm all of which are 0 to 2 percent slope, and has slight sheet erosion with less than 25% of top soil removed, with the exception of one plot which is 7 to 12 percent slope and moderate sheet erosion with 25 to 75 percent of top soil removed.

The organic content of this soil is 5.03. This indicates that this is a mineral soil. The moisture content of the soil in this problem is significant, in that it gives a rough indication of the particle size.

The cation exchange capacity of this soil is 29.62 milliequivalents per 100g. This indicates that this soil has the capacity to react as the hydrous mica clays.

Soil number 21 (Fig. 3) is classified as being a brown blue grass maury soil with permeable subsoil. It appears in nine different plots, with three different slopes. Five plots have slopes from 2 to 7 percent; three plots have slopes from 7 to 12 percent; and one has a slope from 12 to 20 percent. The degree of erosion ranges from 25 to 75 percent to over 75 percent of top soil removed by moderate sheet erosion.

The organic content of this soil is 5.80 percent, which indicates that this is a mineral soil. This is slightly higher than soil number 10.

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The organic content of this soil is 5.80 percent, which indicates that this is a mineral soil. This is slightly higher than soil number 10.

The cation exchange capacity of this soil is 21.92 M. E. per 100 grams of soil. It is believed that the cation exchange capacity is lower in 21 than is 10 because 21 has more soil washed away than 10: Therefore, in collecting the samples more of the B horizon or the subsoil was taken. It has been found that subsoils have a lower cation exchange capacity than top soils. Were it not for the added organic content the exchange capacity might have been much lower.

Soil number 40 (Fig. 3) is classified as being a medium drained first bottom Lindside soil. It appears in two different plots.

One plot has a 0 to 2 percent slope, and one has a 2 to 7 percent slope.

The degree of erosion is plus erosion.

The organic content of this soil is 6.09 percent. The percentage of organic matter content in this soil is higher than in either number 10 or 21. This is thought to be due to the fact that this land is not as well drained as the other two soils mentioned, thus retarding the decomposition of the organic matter in the soil.

The cation exchange capacity of this soil is 37.81 milliequivalents per 100g of soil. The high milliequivalents in this soil is thought to be due to the high content of organic matter contained therein.

Soil number 42 (Fig. 3) is classified as being a medium drained brownish grap Dickson soil, with a compact layer (pan) in the subsoil. This soil appears in two different places, each one being located on the top of a narrow ridge. The slope of one is from 2 to 7 percent, and

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the other from 7 to 12 percent. The degree of erosion is moderate sheet erosion with over 75% of the top soil removed.

The organic matter content of this soil is 6.86 percent. The organic matter content of this soil is somewhat higher than No. 40. This is thought to be due to the fact that drainage here is not as extensive as in several other plots, and the decomposition of the organic contents has not been as extensive.

The cation exchange capacity of this soil is 25.41 milliequivalent per 100 grams of soil. The milliequivalent of this soil is thought to be lower than number 40 because the presence of the compact layer (pan) in the subsoil indicates that the finer soil particles have leached out of the surface soil leaving a greater proportion of coarse particles. The coarse particle soil has a lower milliequivalent per 100 grams of soil than does the small particles thus explaining the low results found.

Soil number 61 is classified as being land too stony to plow.

It is a maury stony soil: this type of land only comprises one area.

The slope is from 12 to 29 %, and the degree of erosion is moderately severe sheet erosion. This land at present is in pasture.

The organic matter content of this soil is 6.95 percent. Since no cultivation has gone on to hasten decomposition of the organic matter, it is understandable why a pasture soil would be this high in organic matter content.

The cation exchange capacity is 20.61 milliequivalents per 100 grams of soil. This is somewhat low as compared to other plots but is

the other from 7 to 12 percent. The degree of erosion is moderate sheet erosion with over 75% of the top soil removed.

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thought to be due to the coarse texture of the soil and to the state of activity of the organic content.

Soil number 81 (Fig. 3) is classified as being a dark colored wet dunning soil. This soil appears in two plots each having a 0 to 2 percent slope and plus erosion. This area remains wet longer than the surrounding land, as it is lower.

The organic matter content of this soil is 8.68 percent. This is higher than any other plot on the farm, and is thought to be due to the amount of water contained on this soil. Water tends to cool the soil, thus retarding the decomposition of the organic matter.

The cation exchange capacity of this soil is 24.09 milliequivalents per 100 grams of soil. This is lower than would be expected on a soil containing 8.68 percent organic matter content but it is believed that the low exchange capacity is due to large partions of coarse material being brought down by erosion from adjacent plots, and coarse particle soils having a lower milliequivalent per 100 grams of soil than fine particles have influenced the results greatly. It is also thought that the state of decomposition of the organic matter has influenced the cation exchange capacity.

Soil number 83 (Fig. 3) is classified as being a poorly drained gray first bottom Melvin soil. This soil only comprises one area. The slope is 0 to 2 percent and has plus erosion.

The organic matter content of this soil is 6.59 percent. The organic matter content is high possibly because the plot is poorly drained

thought to be due to the coarse texture of the soil and to the state of activity of the organic content.

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The cation exchange capacity of this soil is 24.09 millisquivalents per 100 grams of soil. This is lower than would be expected on a soil containing 3.66 percent organic matter content but it is believed that the Low exchange capacity is due to large partions of coarse material being brought down by erosion from adjacent plots, and coarse particle soils having a lower millisquivalent per 100 grams of soil than fine particles have influenced the results greatly. It is also thought that the state of decomposition of the organic matter has influenced the cation exchange capacity.

Soil number 83 (Fig. 3) is classified as being a poorly drained grey first bottom Melvin soil. This soil only comprises one area. The slope is 0 to 2 percent and has plus erosion.

The organic matter content of this soil is 6.59 percent. The organic matter content is high possibly because the plot is poorly drained

and the decomposition of organic matter has been retarded.

The cation exchange capacity of this soil is 39.28 milliequivalent per 100 grams. This is also high but is thought to be due to the large amount of organic matter content plus the fact that this plot, having plus erosion and being subject to floods has had small particles of soil deposited there during the flood periods.

The following complantons were mades .

- ter content, and cation emmanye capacity, the high cation exchange capacity is due to the migh percentage of organic matter.
- 2. In soils with a low organic matter content, high moisture content, and nigh cation exchange objective the nigh cation exchange chassing to the particles
- In soils with a low pointure content, when present matter content, and low cuclon exchange constity, the outtant auchange capacity would have been such lower had it not need for the high organic matter postents.
- and high cation explange capacity, the high engants scattent, and high cation explange capacity, the high ention explange capacity is one book to the mineral fraction and the organic fraction.
- that the organic matter in this soil is in a state of disintergration, may not not read at the stage of decomposition; whereas, it can contribute to the capion exchange sapacity, however, when this stage of necessoration is reached, the partice exchange capacity will be reasonable as concordingly.
- 6. Additional study is desired before the fall explanation of the reason as no sty the soil having high organic content and his moisture content still has a relatively los dation exchange days it.

and the decomposition of organic matter has been retarded.

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## SUMMARY AND CONCLUSIONS

The most outstanding facts revealed by this study are that:

1. The moisture content of these soils ranged from 2.02 in Maury Stony (61) to 3.79 percent in the Dunning (81).

2. The organic matter content of these soils ranged from 5.03 in the Huntington to 8.68 percent in the Dunning (81).

3. The cation exchange capacity of these soils ranged from 20.61 in the Maury Stony to 39.28 M. E. per 100 grams of soil in the Melvin (83).

The following conclusions were made:

#### SOILS

- 1. In soils having a low moisture content, a high organic matter content, and cation exchange capacity, the high cation exchange capacity is due to the high percentage of organic matter.
- 2. In soils with a low organic matter content, high moisture content, and high cation exchange capacity, the high cation exchange capacity is due primarily to the size of the particles.
- 3. In soils with a low moisture content, high organic matter content, and low cation exchange capacity, the cation exchange capacity would have been much lower had it not been for the high organic matter content.
- 4. In soils with a high moisture content, high organic content, and high cation exchange capacity, the high cation exchange capacity is due both to the mineral fraction and the organic fraction.
- 5. In soils with a high moisture content, high organic matter content, but low in cation exchange capacity, it is thought that the organic matter in this soil is in a state of disintergration, but has not reached the stage of decomposition; whereas, it can contribute to the cation exchange capacity. However, when this stage of decomposition is reached, the cation exchange capacity will be raised accordingly.
- 6. Additional study is needed before the full explanation of the reason as to why the soil having high organic content and high moisture content still has a relatively low cation exchange capacity.

ne most outstanding facts revealed by this study are that:

- 1. The modsture content of these soils ranged from 2.02 in the Dunning (81).
  - 2. The organic matter content of these soils ranged from 5.03 in the Huntington to 3.68 percent in the Dunning (81).
- 3. The cation exchange depactby of these soils ranged from 20.61 in the Laury Stony to 39.28 ff. E. per 100 grams of soil in the Melvin (83).

The following conclusions were made:

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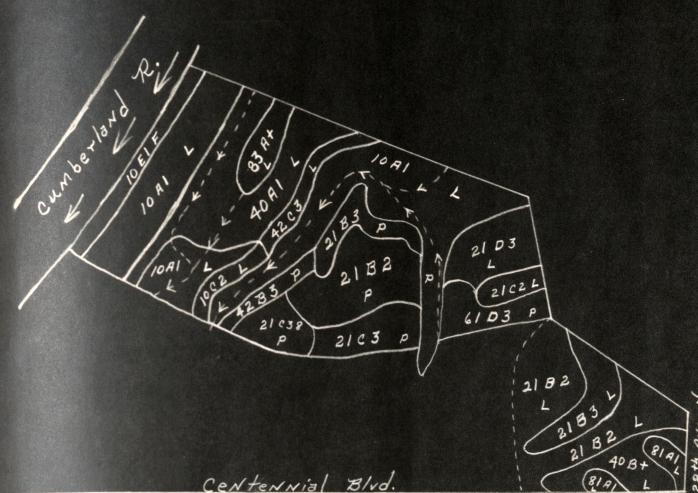
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- 6. Additional study is needed before the full explanation of the reason as to why the soil having high organic content and high moisture content still has a relatively low cation exchange capacity.

# THE FOLLOWING RECOMMENDATIONS ARE MADE:

- 1. According to the cation Exchange capacity found, Soils numbered 83 Melvin and 40 Lindside (Fig. 3) are capable of utilizing larger amounts of commercial fertilizers than other soils on the farm. The quantity used on the other Soils should be in the following order, from large to small amounts: No. 10 Huntington, 42 Dickson, 81 Dunning, 21 Maury, and 61 Maury Stony.
- To soils number 10 Huntington, and 21 Maury, organic matter should be added in the form of green manure, barnyard manure, plant residue, or any other form available.
- 3. When limed, the calcium will remain in soils with high cation exchange capacity longer than in soils with low cation exchange capacity. The leaching of calcium will be in the following order: the least will be in soil 83 Melvin, followed by 40 Lindside, 10 Huntington, 42 Dickson, 81 Dunning, 21 Maury, and 61 Maury Stony, in that order.

It is believed that the above information will be of great assistance in the management of the Farm at the TENNESSEE AGRICULTURAL AND INDUSTRIAL STATE COLLEGE.



(Fig. 3 ) Tennessee A. & II State College Farm as classified by the district soil conservation department Nashville, Tennessee - February 1947

10 - Huntington

40 - Lindside

21 - Maury

42 - Dickson

61 - Maury

81 - Dunning

83 - Melvin

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# UTILITARIAN SOIL CONSERVATION LEGEND Davidson County, Tennessee

# SOIL GROUPS

- 10. Well Drained brown first bottom soils.
- 20. Brown or Reddish brown silt loams low in phosphate.
- 21. Brown blue grass soil with permeable subsoil.
- 30. Cherty soils with yellow subsoil.
- 31. Cherty soils with reddish subsoil.
- 32. Well drained chert free surface soils with yellow or reddish subsoil.
- 40. Medium drained first bottom soils.
- 42. Medium drained brownish gray soils with a compact layer (Pan) in the subsoil.
- 50. Dark colored bluegrass soils with yellow plastic subsoil.
- 51. Brownish gray soils with reddish plastic subsoil.
- 53. Grey soils with yellow plastic clay subsoils.
- 55. Shallow bluegrass soils with yellow and grey plastic clay subsoil.
- 61. Land too stony to plow.
- 62. Low phosphate stony soils where lowing is possible.
- 63. Moderately deep silty clay loam soils with shaley or sandy high phosphate subsoils.
- 65. Cherty phosphatic soils with greyish brown surface and permeable subsoil.
- 66. Shallow soils over shale.
- 68. Stony bluegrass soil where plowing is possible.
- 80. Wet soils of the stream terraces.
- 81. Dark colored wet soils.
- 83. Poorly drained grey first bottom soils.

# EROSION SYMBOLS

- Unclassified erosion
- + Recent accumulations
- 1. Slight sheet erosion- less than 25% of top soil removed.
- 2. Moderate sheet erosion 25 to 75% of top soil removed.
- 3. Moderately severe sheet erosion-over 75% of top soil removed.
- 4. Severe sheet erosion-sheet erosion into subsoil.
- 5. Very severe sheet erosion-sheet erosion into parent material.
- Occasional gullies.
   Frequent gullies.
- 8. Very frequent or destructive large gullies.

Note: Gullies too large to be crossed by tillage implements are indicated by encircling the symbols

# UTILITARIAN SCIL CONSERVATION LICENDE Davidson County, Tennessee

# SOIL GROUPS

10. Well Drained brown first bottom sails.
20. Brown or Reddish brown sailt loams low in phosphate.

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31. Cherty soils with reddien subsoil.

32. Well dreined chert free surface soils with yellow or reddish subscil.

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4. Severe sheet erosion-sheet erosion into subsoil.

5. Very severe sheet erosion-sheet erosion into parent material.

. Cocasional gullies.

7. Frequent gullies.

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wents are indicated by encircling the symbol.

LAND USE

LATERATURE OF RES

SLOPE LEGEND

1 - crop land
p - pasture
pb-Brushy pasture
X -Idle Land
D -12 -20
F -Woodland
H -Non-agricultural

A - 0 - 2 percent
B - 2 - 7 "
C - 7 -12 "
D -12 -20 "
F -0ver 30 "

SEQUENCE OF SYMBOLS

soil type -- slope -- Erosion

The Matter and propertion of Soils. Fourth Million, No. 2014 C. Poe Manuallan Company 1969 PP. 70-83

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151 and Plant Analysis New York: Intersciance Publishers

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Soll changes Associated with Thilage and Grapping in Hould Arons of the United States. Journal of the American Social of Agrocemy. 33: September 1961 Sp. 755-777

## Chrom a 1918

A - 0 - 2 percent
B - 2 - 7 "
C - 7 - 12 "
D - 12 - 20 "
E - 20 - 30 "
F - Over 20 "

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SECURIOR OF STABULS

soil type - slope -- brosion

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