U. of M.

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report
of
Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given Jouette Clark Russel final oral examination for the degree of Master of Science . We recommend that the degree of Master of Science be conferred upon the candidate.

Minneapolis, Minnesota
June 1 1918

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THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report
of
Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Jouette Clark Russel for the degree of Master of Science. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

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THE RELATION OF CERTAIN PHYSICAL AND CHEMICAL PROPERTIES TO THE SOIL CLASS

By

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A THESIS

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INTRODUCTION.

At the present time the classification of soils in the United States is based upon the mechanical analysis of samples selected as representative by experienced field men. The mechanical analysis itself is a very delicate, tedious and time-consuming operation, and hence it is expensive in the case of any survey involving large tracts of land varying greatly in the texture of the soil. The field men, taking numerous samples as they go, rub them between thumb and finger and examine them with the unaided eye, and on the spot decide as to whether they are loams, silt loams, etc. After an area has been surveyed, the field men collect from each type, one or more samples which they consider representative, and these are subjected to mechanical analysis. Thus it comes about that the mapping of the soils is based almost exclusively upon the judgment of the field man while the actual mechanical analysis is used chiefly to confirm his estimate, or to interpret his classification in terms of the proportions of the soil separates of different sizes.

The disadvantages of the above method have come to be quite generally realized, and the Committee on Soil Classification of the American Society of Agronomy, at its last meeting, has proposed that there be reported actual determinations of some physical constant, such as the moisture equivalent or the hygroscopic coefficient, and chemical data showing the content of nitrogen and organic matter, and the relative calcareousness; the last is also commonly referred to as the adequacy of the lime supply, or as the degree of soil acidity (13). The object of this proposal is to permit of a more rigid definition of the soil types, and so to leave less to the decision of the individual field men, who themselves feel their judgment constantly in need of laboratory assistance, confirmation or interpretation.

The author has attempted in the case of the soils of Ramsey County to determine what relations exist between both the moisture equivalent and the hygroscopic coefficient and the soil class, as it has been defined by the Bureau of Soils, and also to ascertain what relations exist between the nitrogen content and the degree of acidity on the one hand and the physical constants, or texture, of both soil and subsoil on the other.

The object of soil classification is to divide soils into areas of approximately uniform crop producing powers and agricultural relations. The U. S. Bureau of Soils, which has already mapped more than 500,000 square miles, uses as its unit the soil type, this being limited to a single class in a single series. A soil type throughout the area of its occurrence is supposed to have the same texture, color, structure, character of subsoil, general topography, and processes of derivation; usually it is derived from the same material.

The class name, such as loam, silt loam, etc., indicates only the texture of the surface material, the depth which is stirred by the tillage implements in the course of cultivation, all other characteristics of the type being indicated by the series name, such as Fargo, Barnum, Wabash, etc., this being derived from the name of some town, village or natural feature existing where the series was first encountered.

A series constitutes a group of soils, having certain characteristics, namely, same range in color, same character of the subsoil, same type of relief and drainage, and lastly a common or similar origin.

A class, on the other hand, includes all soils of similar texture and may occur in every series. The more common soils, on the basis of their content of clay, silt and sand, may be divided into 12 classes, as shown in the following scheme.

A. Soils containing less than 20 per cent of silt and clay.

1. Coarse sand - more than 25 per cent of fine gravel and coarse sand, and less than 50 of any other grade.

2. Sand - more than 25 per cent of fine gravel, coarse and medium sand, and less than 50 per cent of fine sand.

3. Fine sand - more than 50 per cent of fine sand, or less than 25 per cent gravel, coarse and medium sand.

4. Very fine sand- more than 50 per cent of very fine sand.

B. Soils containing from 20 to 50 per cent of silt and clay.

5. Sandy loam - more than 25 per cent of fine gravel, coarse and medium sand.

6. Fine sandy loam - More than 50 per cent of fine sand, or less than 25 per cent gravel, coarse and medium sand.

7. Sandy clay - less than 25 per cent silt and more than 20 per cent of clay.

C. Soils containing more than 50 per cent of silt and clay.

8. Loam - less than 20 per cent of clay and less than 50 per cent of silt.

9. Silt loam - less than 20 per cent of clay and more than 50 per cent of silt.

10. Clay loam - from 20 to 30 per cent of clay and more than 50 per cent of silt.

11. Silty clay loam - from 20 to 30 per cent of clay and more than 50 per cent of silt.

12. Clay - more than 30 per cent of clay.

COMPUTATIONS FROM THE DATA OF SWANSON.

A number of the State Agricultural Experiment Stations have followed up the soil survey with the chemical analysis of representative samples from the different types shown on the soil survey maps. Swanson has reported analyses of practically all of the soil types that have so far been identified in Kansas (14, 15, 16). This work and the mechanical analyses of samples from the same types by the Bureau of Soils (4 to 11) are brought together in Tables I and II with the idea of finding any relationships that may exist between the soil class and the nitrogen content. It should be emphasized that the class designation is not a very exact description of the soil texture, as any class may include soils that differ rather widely in the relative proportions of the mechanical separates. A single-valued physical constant, such as the moisture equivalent, or the hygroscopic coefficient, dependent upon the internal surface, is to be regarded as a more satisfactory expression of the texture. Both may, with some degree of exactness, be calculated from the mechanical analysis, and for this, several different formulas have been proposed.

For the loess soils of Nebraska, Alway and Russel (2,p.842) have deduced the formula: Moisture equivalent = 0.14 total sands + 0.27 silt + 0.53 clay. As the soils studied by Alway and Russel were uniformly very low in the coarser particles, those with a diameter greater than 0.1 mm., the formula has been modified for the Kansas soils, which in some cases contain a high percentage of these coarser particles, so that it becomes - Moisture equivalent = 0.02 coarser particles + 0.14 very fine sand + 0.27 silt + 0.53 clay. Using this I have calculated the moisture equivalents for the different soils types.

Table I - Relations of computed moisture equivalent, nitrogen, and organic matter in Kansas soils to the soil class, as shown by the data of C. O. Swanson.

Soil No.	Soil Type	County	Coarser particles	Very fine sand	Silt	Clay	Moisture equivalent	Nitrogen	Organic carbon	Ratio C/N
			pct.	pct.	pct.	pct.		pct.	pct.	
				CLAYS						
1	Sharkey Clay	Allen	3.6	2.4	54.2	39.8	36.1	.267	2.79	10.4
2	Yazoo do	do	2.8	6.1	58.7	32.4	34.0	.269	2.69	10.0
3	Kirkland do	Reno	10.3	8.1	41.8	39.8	33.7	.205	2.03	9.9
				SILT LOAMS						
4	Marshall silt loam	Brown	1.7	3.8	65.0	29.5	33.6	.221	2.70	12.2
5	Oswego do	Riley	3.5	6.9	71.8	17.8	29.9	.217	2.60	12.0
6	Wabash do	do	3.4	10.2	68.6	17.8	29.4	.188	2.11	11.2
7	Marshall do	do	5.2	13.6	61.3	19.9	29.1	.205	2.02	9.8
8	Osage do	Shawnee	8.6	16.5	51.9	23.0	28.7	.168	2.16	12.9
9	Marshall do	Finney	4.7	19.8	55.3	20.2	28.5	.124	1.16	9.4
10	Oswego do	Allen	3.3	9.7	73.4	13.6	28.5	.220	2.51	11.4
11	Neosha do	do	9.0	12.5	63.4	15.1	27.1	.166	1.58	9.5
12	Laurel do	Riley	7.3	15.9	66.6	10.2	25.7	.252	2.75	10.9
				SILTY CLAY LOAMS						
13	Oswego silty clay loam	Shawnee	1.9	3.5	62.6	32.0	34.4	.177	1.90	10.7
14	Osage do	do	1.3	5.8	61.4	31.5	34.1	.201	2.47	12.3
15	Crawford do	do	2.0	3.9	67.6	26.5	32.9	.255	2.78	10.7
16	Summit do	do	10.9	5.9	54.9	28.3	30.8	.275	3.38	12.3
17	Pratt do	Reno	4.4	16.1	55.5	24.0	30.1	.161	1.82	11.3
				CLAY LOAMS						
18	Sedgwick clay loam	Allen	3.4	8.9	66.4	21.3	30.5	.217	2.40	11.1
19	do	Russell	4.3	10.5	75.5	9.7	27.1	.187	2.14	11.4

Table I continued

Soil No.	Soil Type	County	Coarser particles pct.	Very fine sand pct.	Silt pct.	Clay pct.	Moisture equivalent	Nitrogen pct.	Organic carbon pct.	Ratio C/N
				CLAY LOAMS						
20	Arkansas clay loam	Reno	21.9	18.4	38.8	20.9	24.6	.181	2.08	11.5
21	Clark do	do	32.6	11.5	32.1	23.8	23.6	.173	1.80	10.4
				LOAMS						
22	Yazoo loam	Allen	2.5	8.6	70.7	18.2	30.0	.173	1.83	10.6
23	Benton do	Russell	22.2	15.0	31.4	31.4	27.6	.237	2.90	12.2
24	Derby do	Sedgwick	11.5	27.6	42.0	18.9	25.4	.152	1.69	11.1
25	Pratt do	Reno	19.3	18.7	42.1	19.9	24.9	.170	1.87	11.0
26	Arkansas do	Sedgwick	12.6	20.4	54.0	13.0	24.7	.191	2.04	10.7
27	Laurel do	Finney	25.2	21.8	30.8	22.2	23.7	.168	1.52	9.0
28	Sedgwick do	Sedgwick	18.8	11.7	59.6	9.9	23.3	.181	1.97	10.9
29	Albion do	Reno	35.3	10.7	33.2	20.8	22.2	.150	1.67	11.1
30	Arkansas do	do	28.6	21.5	31.5	18.4	21.9	.139	1.55	11.1
31	Clark do	do	44.2	13.9	23.2	18.7	19.0	.106	.98	9.2
				FINE SANDY LOAMS						
32	Oswego fine sandy loam	Allen	9.4	31.1	46.9	12.6	24.0	.155	1.63	10.5
33	Boone do	Shawnee	38.4	13.4	26.2	22.0	21.5	.138	1.48	10.7
				SANDY CLAY LOAMS						
34	Pratt sandy clay loam	Reno	46.3	12.2	22.6	18.9	18.7	.148	1.43	9.7
				SANDY LOAMS						
35	Sedgwick sandy loam	Russell	37.3	25.4	27.6	9.7	16.9	.141	1.61	11.4
36	Laurel do	Finney	42.2	26.5	18.4	12.9	16.3	.090	0.82	9.0
37	Finney do	do	47.2	17.1	23.1	12.6	16.2	.074	0.64	8.7
38	Albion do	Reno	51.1	10.2	27.7	11.0	15.7	.095	1.11	11.7
39	Sedgwick do	Sedgwick	60.5	18.5	14.0	7.0	11.3	.099	1.03	10.4

Table 11 - Relation of moisture equivalent, nitrogen, and organic matter to soil class, computed from the data of C. O. Swanson. Averages of data in Table 1.

Soil Class	Number included	Coarser particles pct.	Very fine sand pct.	Silt pct.	Clay pct.	Moisture equivalent	Nitrogen pct.	Organic carbon pct.	Ratio C/N	Ratio ME/N
Clays	3	5.6	5.5	51.6	37.3	34.6	.247	2.50	10.1	140
Silty clay loams	5	4.1	7.0	60.4	28.5	32.5	.214	2.46	11.5	152
Silt loams	9	5.2	12.1	64.1	18.6	28.9	.196	2.18	11.1	147
Clay loams	4	15.6	12.3	53.2	18.9	26.5	.190	2.11	11.1	140
Loams	10	22.0	17.0	41.9	19.1	24.3	.167	1.80	10.8	145
Fine sandy loams	2	23.9	22.3	36.5	17.3	22.8	.147	1.56	10.6	155
Sandy clay loams	1	46.3	12.2	22.6	18.9	18.7	.148	1.43	9.7	126
Sandy loams	5	47.7	19.5	22.2	10.6	15.5	.100	1.04	10.4	153
Average of all -	39	21.3	13.5	44.1	21.1	25.5	.176	1.89	10.7	145

The mechanical analyses, the calculated moisture equivalents, and the nitrogen and organic carbon content of the surface seven inch section have been tabulated in Table I. The ratio of organic carbon to nitrogen (C/N) is also shown. The soils have been arranged by classes according to decreasing moisture equivalent. Three points must be recognized in the interpretation of the data. First, the samples on which mechanical and chemical analyses were made were not the same, two different sets of samples being taken by different parties and in almost all cases from different fields, but it is assumed that both are truly representative of the types. The moisture equivalent of soils of the same type may differ by several per cent, and hence, some variation must be expected from field to field. Next, the formula of Alway and Russel is not to be regarded as entirely satisfactory with soils not of loessial origin. However, variations due to the latter cause may possibly be no greater than those due to the former. Lastly, not all of the samples of which chemical analyses were made were secured from virgin fields. No information on the point is given in the publications but Swanson in a private communication has informed the author that some were from cultivated fields. For this reason the C/N ratio is included in the table. Hence, from sample to sample the calculated moisture equivalents and the nitrogen content are not to be expected to show an <u>exact</u> relationship, and it is only when we consider the averages for the different types that any thing like a definite relation is to be expected.

In a general way the nitrogen content is shown to decrease as the moisture equivalent decreases. Out of the thirty-nine soils, two of the three highest in nitrogen content stand at the beginning of the list with the highest moisture equivalents. The one highest in nitrogen content is found in the middle of the table. The four soils with the lowest nitrogen contents are found at the very end of the table. When the data for soils of a class are averaged it is seen that with the eight soil classes the order of nitrogen contents is the same as the order of moisture equivalents with one exception, where the averages are based on one and two soils. The relation is more striking when the ratio of moisture equivalent to nitrogen (ME/N) is calculated. It varies from 126 to 155, averaging 145. The two most exceptional ratios are for the two classes noted above. The individual ratios agree with each other within about 10 per cent. On the basis of the data as a whole, and the averages in particular, it can be concluded that for Kansas soils there is a natural tendency toward a linear relationship of nitrogen to moisture equivalent.

The ability of the moisture equivalent determination to express soil class is a point to be noted in the table. On the average, no two soil classes have the same moisture equivalent. The clay class has the highest value, followed by silty clay loams, silt loams, and loams. When these values are applied to individual soils within the classes it is seen that the departures are numerous and wide: however, no more so than the departures from the average mechanical analyses. If the mechanical analyses instead of the field man's judgment were depended upon for classification, about the same exceptions to class would be noted. Soils 13 and 14 on the basis of mechanical analysis and moisture equivalent do not differ from soil 2. Soils 18 and 22 agree well with soils 5 and 6. Soil 21 is not different from 29. Soils 31 and 34 have about the same mechanical composition as well as moisture equivalent. The conclusion can be strictly drawn that the moisture equivalent is just as expressive of soil texture as the mechanical analysis.

SOIL TYPES STUDIED.

The field work was limited to Ramsey County, in which the Minnesota Agricultural Experiment Station is located. The survey of the area was made in 1914 by Smith and Kirk (12), the former being one of the most experienced field men in the U. S. Bureau of Soils, he having entered the service very soon after the field work was organized and having continuously worked in the field for about twenty years. Moreover, he is one of the earliest graduates of the College of Agriculture of the University of Minnesota and began his soil survey work in Ramsey County, and so was especially equipped for accurate, detailed survey work in this particular area. Accordingly, the mapping of types in the county is to be considered as accurate as is possible under the system employed. Eighteen types, representing ten series and five classes, were identified in the county. Eleven types, representing all five classes and six of the series, are included in the present study. The seven other types did not lend themselves to the work, they including rock outcrop, marsh, etc. A brief description of the six series follows, it being in part based upon the report of Smith and Kirk and in part upon the author's observations in Ramsey County.

The Clyde series is represented in this study by only one type, Clyde silt loam. The members of this series have black surface soils with gray subsoils, derived from the deposition or reworking of material deposited in glacial lakes and ponds. The surface soils are high in organic matter, and fairly high in lime, the lower levels often grading into marl. They occupy level and poorly drained areas.

The Hempstead series, represented by two classes, the silt loam and fine sandy loam, is derived from water-laid material of glacial outwash plains. The surface soils are dark brown to black and underlaid by yellowish brown subsoils. The subsoil is usually of a somewhat coarser texture than the surface, and at depths ranging from three to five feet there is found a layer of sand or gravel.

The Merrimac soils, like the Hempstead, are derived from outwash material of glacial lake and river terraces, but the surface soil is lighter in color, being light brown and overlying a yellowish brown subsoil. The subsoils are lighter in texture than the surface soils, the difference being more pronounced than in the Hempstead series. The loam, fine sand, and loamy fine sand classes are represented. The soils of this series show considerable lack of uniformity, due to the varying character of the deposits upon which they have been developed. In some areas these were derived from the Late Red Drift, and in others from the Late Gray Drift. In some areas the primary deposits have been considerably reworked by the action of the wind.

The Miami series includes light brown surface soils underlain by brown to grayish brown subsoils characteristically as heavy as, or heavier than the former. They are derived from glacial deposits of the Gray Drift, accumulations which originally carried a high lime content. Bowlders, cobblestones, and gravel occur throughout the soil profile. The series is represented in this study by two types, the loam and the fine sandy loam.

The Gloucester soils have been derived from the glacial till of the Late Red Drift and hence, the subsoils are of a characteristic reddish-brown color. Bowlders, cobblestones, and gravel, mainly from crystalline and sandstone rocks, occur abundantly. The subsoil is heavier in texture than the surface. The loam and fine sandy loam types are represented.

The Hinckley series has been developed upon kames and eskers, and other water-laid glacial formations. The soils resemble the Miami series in color and also in the distribution of bowlders and gravel, but are non-calcareous. The most obvious difference in the field is the texture of the subsoil which is coarser than the surface.

FIELD METHODS.

In the case of each type three extensive areas, as widely separated as possible, were selected from the map, and these were gone over carefully in order to decide which fields were most satisfactory and in the case of each area three fields sampled. Usually those in any one of the three areas were not more than a mile apart. In the case of two types, Clyde silt loam, and Hempstead silt loam, only two areas were available, and in the case of both the Hempstead fine sandy loam and the Hinckley loamy fine sand, only one. On account of the practical disappearance of virgin fields typical of most of the types, nearly all of the samples were taken from fields that had been under cultivation many years, but it was attempted to avoid fields that had probably received any unusually heavy applications of manure.

From the surface six inches of each field a composite was made of ten individual samples taken with a brass tube with a constricted cutting edge. The individual samples were taken ten paces apart in a straight line across the field except where this method was impracticable. Subsoil samples were not taken from every field, but from only one of the three in each area, three borings being made in a field and the individual samples composited. After cleaning out a boring to a depth of one foot with a two inch auger, the second foot was taken with a 1.5 inch auger, the hole again cleaned out with the two inch auger, and the third foot section taken. No samples were taken from the second half of the first foot. Accordingly, with the exceptions mentioned above, each soil type is represented by 90 individual samples of surface soil, and by 9 samples from both the second and the third foot levels.

PREPARATION OF SAMPLES.

The samples were exposed in the laboratory until air-dry, then reduced under a wooden rolling pin, and thoroughly mixed on an oilcloth. A portion was again reduced under the rolling pin, the larger pebbles being cracked with a hammer, one fourth retained for the determination of the coarse gravel, that with a diameter greater than 2 mm., and the remainder reduced in an iron mortar so as to pass a 1 mm. sieve. The physical and chemical studies were made on this fine material. The proportion of coarse gravel is reported on Tables III and IV.

HYGROSCOPIC COEFFICIENTS.

Determinations of the hygroscopic coefficient were made on the surface samples, employing the Hilgard method as modified by Alway, Klein and McDole (1), using checks and making duplicate, triplicate or quadruplicate determinations. No duplicates were accepted unless they agreed within 0.4. As check soils two sandy loams, A and B, were used. The variations in these from day to day are shown in Table V.

The hygroscopic coefficients are reported in Table VI and shown graphically in Figs. 1, 2, 3, and 4. In this table, as well as in the tables to follow, the data are arranged to show the relation of the reported values to the soil type, the three fields of an area being grouped together to reveal the variations from field to field, and the averages of these also

Table III - Percentage of coarse gravel in the surface samples.

Area	Field	Silt loams		Loams			Fine sandy loams			Merrimac	Loamy fine sands	
		Clyde	Hempstead	Miami	Merrimac	Gloucester	Hempstead	Miami	Gloucester	fine sand	Merrimac	Hinckley
1	1	0	2.7	1.4	5.5	4.1	0	5.3	3.1	0	0	3.9
	2	0	0.	0.	1.6	3.5	0	3.2	4.6	0	0	0.
	3	0	0.	2.3	2.4	3.5	0	2.3	4.0	0	1.5	0.
II	4	0	0	2.8	1.2	3.0	---	3.5	4.9	0	5.1	---
	5	0	---	2.7	1.4	6.5	---	1.1	5.0	0	6.8	---
	6	---	---	5.7	0.	3.9	---	6.4	10.0	0	2.2	---
III	7	---	---	3.4	6.3	4.4	---	5.5	4.7	0	0.	---
	8	---	---	0.[a]	1.9	1.7	---	3.6	2.6	0	0.	---
	9	---	---	1.6[a]	2.3	2.4	---	1.0	4.6	0	0.	---
I- Average		0	0.9	1.2	3.2	3.7	0	3.6	3.9	0	0.5	1.3
II Average		0	0.	3.7	0.9	4.5	---	3.7	6.6	0	4.7	---
III Average		---	---	3.4	3.5	2.8	---	3.4	4.0	0	0.	---
Average for all fields.		0	0.5	2.8	2.5	3.7	0.	3.6	4.8	0	1.7	1.3

(a) Samples not true to type and so not included in the averages.

Table IV - Percentage of coarse gravel in the different levels.

		Silt loams			Loams		Fine sandy loams			Merri-mac fine sand	Loamy	
Area	Depth Foot	Clyde	Hem-stead	Miami	Merri-mac	Glouc-ester	Hem-stead	Miami	Glouc-ester		Merri-mac	Hinck-ley
1	0-½	0	2.7	1.4	1.6	4.1	0	5.3	4.0	0	0	3.9
	2	0	1.2	2.8	1.5	7.6	0	6.0	8.9	0	0	2.6
	3	0	.6	2.5	7.2	6.2	0	4.0	5.8	0	0	2.3
II	0-½	0	0.	2.7	1.2	3.0	0	3.5	4.9	0	5.1	---
	2	0	0.	5.2	5.6	3.5	0	12.2	10.0	0	11.8	---
	3	0	0.	5.0		8.7	0		10.3	0	13.1	---
III	0-½	---	---	3.4	6.3	2.4	---	5.5	4.7	0	0.	---
	2	---	---	7.2	.7	4.2	---	0.	7.0	0	0.	---
	3	---	---	5.6	0.	2.4	---	14.1	6.6	0	0.	---
Average	0-½	0.	1.4	2.5	3.0	3.2	0.	4.8	4.5	0	1.7	3.9
	2	0.	.6	5.1	2.6	5.1	0.	6.1	9.0	0	3.9	2.6
	3	0.	.3	4.4	3.6	5.8	0.	9.1	7.6	0.	4.4	2.3

Table V - Concordance of values for the hygroscopic coefficients of the check soils found on successive days.

Date	Soil A. Determination 1	Soil A. Determination 2	Soil A. Determination Av.	Soil B. Determination 1	Soil B. Determination 2	Soil B. Determination Av.
Nov. 28	5.8	6.1	6.0	...	...	...
Nov. 29	6.4	5.8	6.1	...	...	...
Nov. 30	5.7	6.0	5.9	...	...	...
Dec. 1	6.0	6.0	6.0	...	...	...
Dec. 21	...	...	...	6.5	6.8	6.7
Dec. 22	...	...	...	6.8	6.5	6.7
Dec. 23	...	...	...	6.4	6.3	6.4
Dec. 25	...	...	...	6.5	6.5	6.5
Dec. 26	...	...	...	6.5	6.5	6.5
Dec. 27	...	...	...	6.7	6.4	6.6
Dec. 28	...	...	...	6.8	6.6	6.7
Dec. 29	...	...	...	6.7	6.7	6.7
Jan. 2	...	...	...	6.9	6.8	6.9
Jan. 3	...	...	...	6.8	7.0	6.9
Jan. 4	...	...	...	7.1	6.7	6.9
Jan. 5	...	...	...	6.6	6.7	6.7
Jan. 9	...	...	...	6.9	6.4	6.7
Jan. 10	....	...	...	6.8	7.1	7.0
Jan. 11	5.7	5.8	5.8	...	...	...
Jan. 12	5.9	5.9	5.9	...	...	...
Jan. 13	5.5	5.8	5.7	...	...	...
Jan. 15	5.6	5.5	5.6	...	...	...
Jan. 16	6.4	5.8	6.1	...	...	...
Jan. 17	...	...	...	6.9	6.5	6.7
Jan. 18	...	...	...	7.0	6.7	6.9
Average	...	...	5.87	...	...	6.7

Temperature, Nov. 28 - 17°C
Temperature, Jan. 18 - 14°C
Daily fluctuation, 1°C

Table VI - The hygroscopic coefficients of the surface samples.

Area	Field	Silt loams		Loams			Fine sandy loams			Merrimac	Loamy fine sands	
		Clyde	Hemstead	Miami	Merrimac	Gloucester	Hemstead	Miami	Gloucester	fine sand	Merrimac	Hinckley
I	1	11.2	7.8	5.1	6.4	3.6	5.4	3.4	4.7	1.35	2.2	1.74
	2	13.7	7.8	4.5	6.2	3.7	4.3	3.4	3.4	1.47	6.0	2.29
	3	12.6	7.7	4.8	6.8	4.2	4.0	3.2	3.7	1.56	5.0	1.90
II	4	20.7	11.2	4.3	6.4	4.2	---	5.5	2.7	1.93	3.3	---
	5	15.8	----	3.4	6.3	4.3	---	2.8	3.1	1.58	4.3	---
	6	----	----	4.5	7.4	4.4	---	2.5	2.2	1.41	2.9	---
III	7	----	----	3.8	3.8	4.8	---	4.4	3.8	1.99	2.04	---
	8	----	----	2.8*	4.7	4.2	---	2.5	3.2	1.60	1.56	---
	9	----	----	2.1*	4.3	4.9	---	2.8	2.5	1.83	2.5	---
I-Average		12.5	7.8	4.8	6.5	3.8	4.6	3.3	3.9	1.46	4.4	1.98
II-Average		18.3	11.2	4.1	6.7	4.3	---	3.6	2.7	1.64	3.5	---
III-Average		----	----	3.8	4.3	4.6	---	3.2	3.2	1.81	2.0	---
Average for all fields.		15.4	9.5	4.2	5.8	4.2	4.6	3.4	3.3	1.64	3.3	1.98

(*) The use of the asterisk throughout all of the tables and figures indicates that the sample not being true to type, has not been included in the averages.

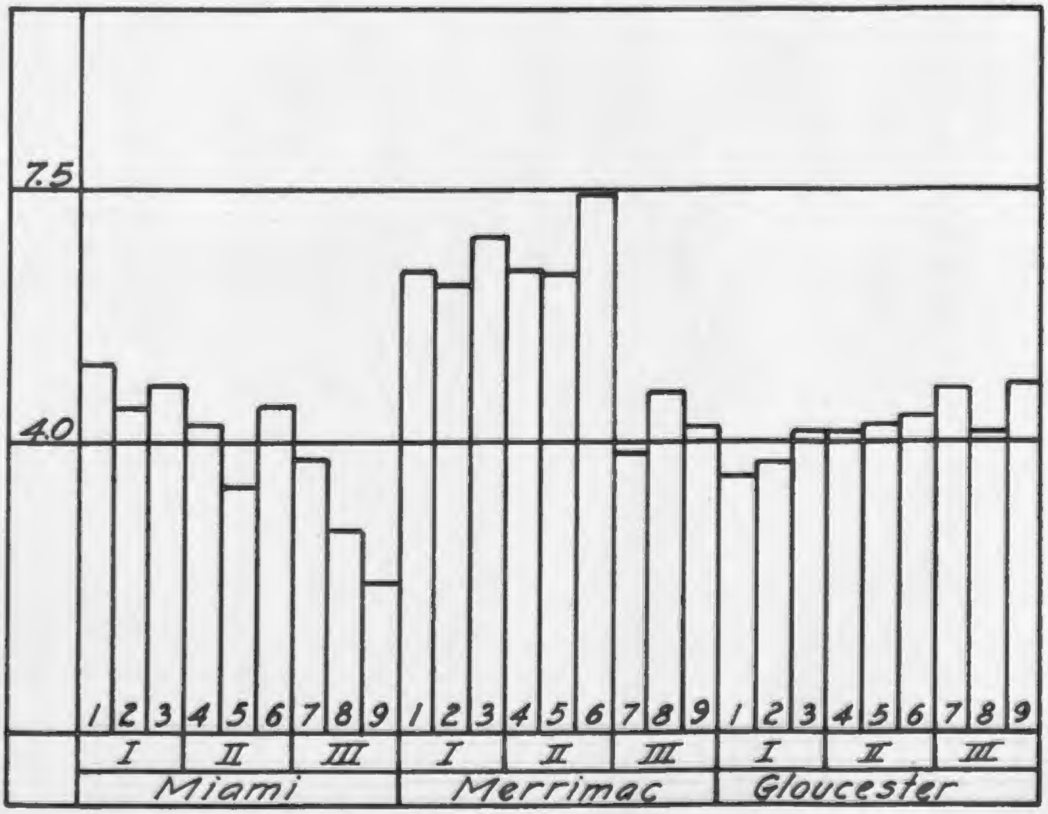
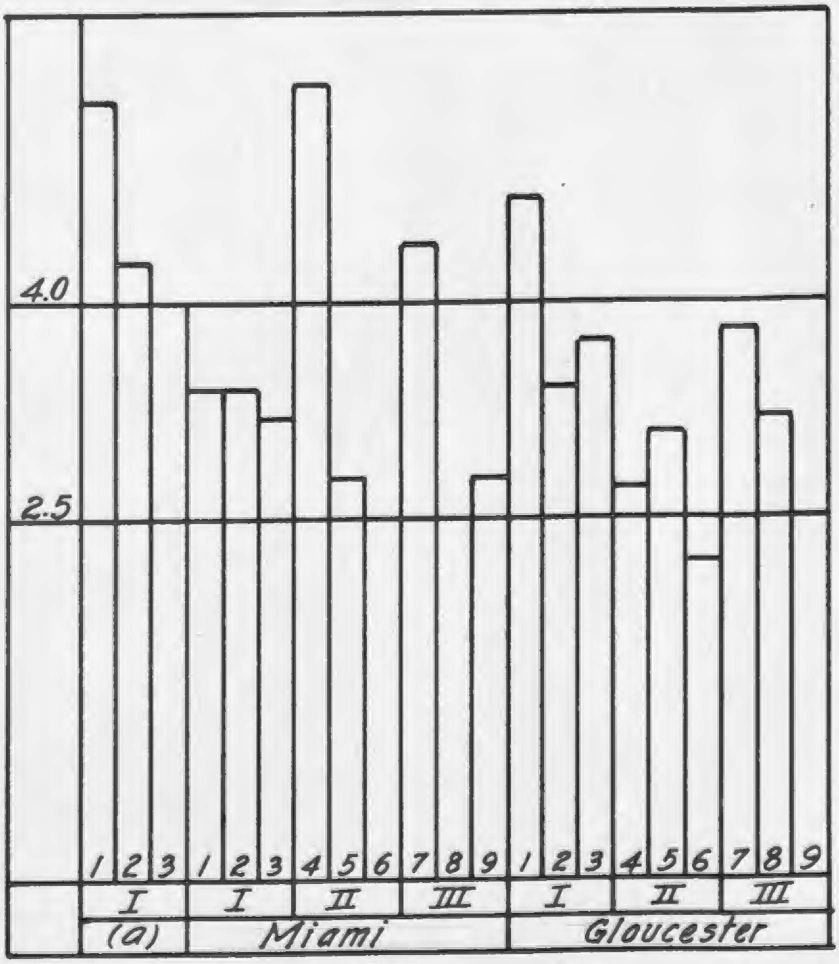
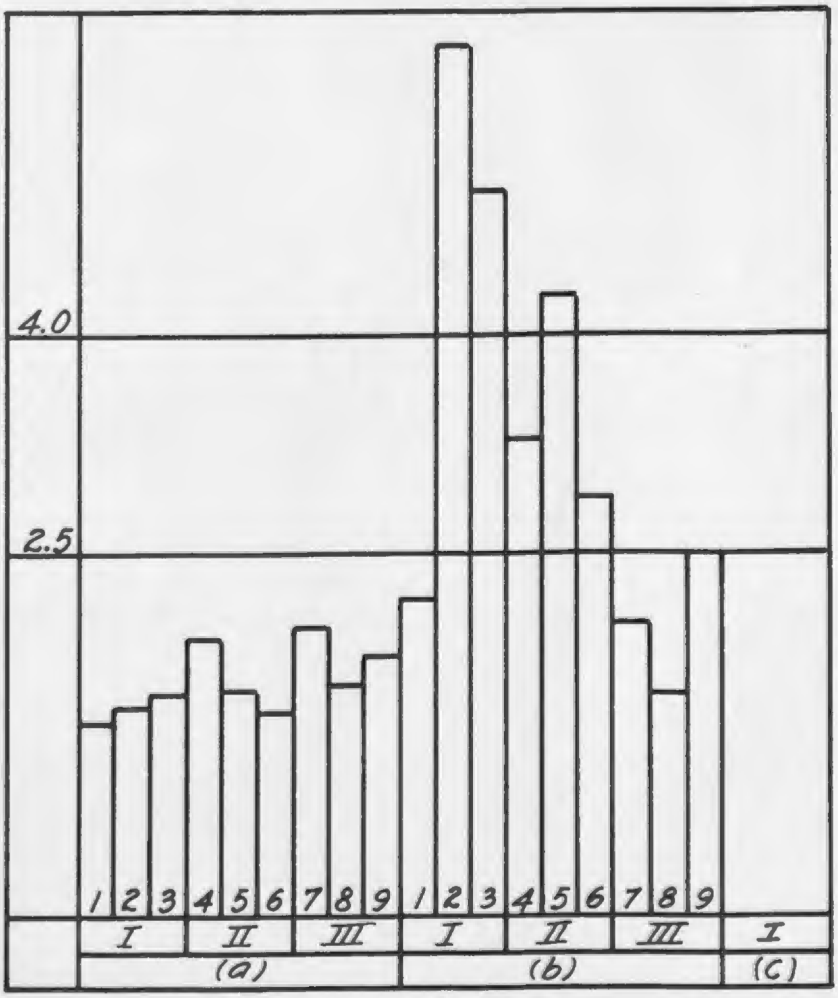


Fig. 1. The hygroscopic coefficients of the loams.



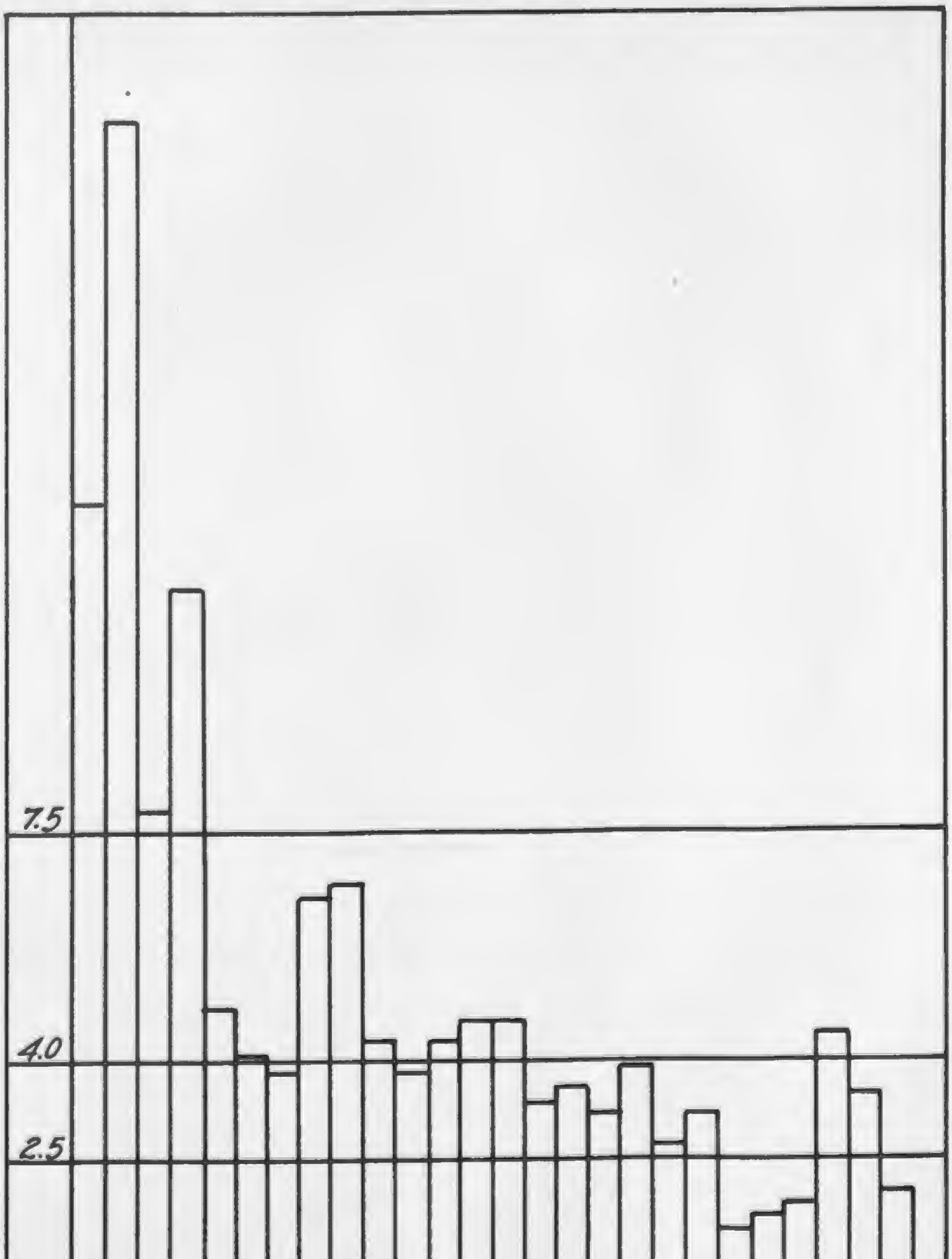
(a) Hempstead

Fig. 2. Hygroscopic coefficients of the fine sandy loams.



(a) Merrimac fine sand.
(b) Merrimac loamy fine sand.
(c) Hinckley loamy fine sand.

Fig. 3. The hygroscopic coefficients of the fine sands and loamy fine sands.



(1) Silt loams, (a) Clyde. (b) Hempstead.
(2) Loams, (c) Miami. (d) Merrimac. (e) Gloucester.
(3) Fine sandy loams. (f) Hempstead. (g) Miami. (h) Gloucester.
(4) Fine sands. (i) Merrimac.
(5) Loamy fine sands. (j) Merrimac. (k) Hinckley.
Fig. 4. The hygroscopic coefficients of the different areas.

grouped to show the variations from area to area. The values for the three areas are in turn averaged so as to show the relations of the property to the texture, as indicated by the field survey and reported in the form of soil classes.

Two sets of samples, those from the eighth and ninth fields of the Miami loam, are not included in the averages in any of the tables, they not being typical of this type. The former is from an "island" of Merrimac loamy fine sand within a large body of Miami loam, and the other field, while on the Miami series, is not a loam.

It will be seen that the hygroscopic coefficient corresponds to the soil class in only a general way. As was to be expected, the values for the silt loams are higher than those for the loams, and the latter in turn higher than those for the fine sandy loams, and these again are higher than those for the fine sands. The agreement between samples from the different fields of the same area is all that one should expect, being as close in most cases as that between individual samples from the same field. From area to area considerable differences are shown, except in the case of the two types, the Gloucester loam and the Merrimac fine sand. The Merrimac loamy fine sand stands out in all the tables on account of its decided lack of any kind of uniformity from field to field.

If the determination of the hygroscopic coefficient were to be substituted for the field examination in mapping soils, it would give quite different results, as may be seen from Figs. 1, 2, 3 and 4. If, on the basis of the above data, a loam were defined as a soil in which the hygroscopic coefficient ranges between 4.0 and 7.5, five of the soils that have been mapped as loams would fall without this class, while six mapped as fine sandy loams, and three as loamy fine sands, would have to be included among the loams. The Hempstead fine sandy loam area would be classified as Hempstead loam. If a fine sandy loam were defined as one whose hygroscopic coefficients range from 2.5 to 4.0, then seven soils mapped as belonging to this class would be excluded and three mapped as loamy fine sands, while five mapped as loams would have to be included.

The low values for the loams and the fine sandy loams shown by the data are of especial interest and will be dealt with in a later paragraph.

MOISTURE EQUIVALENTS.

The moisture equivalent, the determination of which was developed by Briggs and McLane (3), has been proposed for the expression of the relative fineness of texture of soils. The moisture equivalents of the surface samples are reported in Tables VII and VIII and shown graphically in Figs. 5, 6, 7 and 8. If the ratio of the moisture equivalent to the hygroscopic coefficient be practically a constant, the conclusions drawn in the case of the latter value would apply with the moisture equivalent also. The values for the three fields in each area of a type agree satisfactorily, but between areas on the same type the values for the different fields are more discordant , although the average values for the different areas agree with one another as well as the three fields of the individual areas. When in turn the data for the areas are averaged it is seen that the moisture equivalents of the several soil types correspond fairly well with the classes.

If the moisture equivalent determination were to be substituted for the present method of classification, it would not lead to the same result. If on the basis of the data, a loam soil were to be defined as one whose moisture equivalent ranges between 15.0 and 22.0, then seven fields that have

Table VII - The moisture equivalents of the surface samples.

Area	Field	Silt loams		Loams			Fine sandy loams			Merrimac fine sand	Loamy fine sands	
		Clyde	Hemstead	Miami	Merrimac	Gloucester	Hemstead	Miami	Gloucester		Merrimac	Hinckley
I	1	30.7	24.0	21.0	19.7	13.1	14.9	12.3	15.5	3.6	7.1	5.3
	2	33.2	22.8	17.1	20.5	16.3	12.5	13.8	12.9	4.1	26.0	6.0
	3	30.8	22.4	17.7	24.1	16.3	11.6	12.9	13.5	4.4	22.3	5.3
II	4	48.0	32.1	17.1	19.7	17.3	----	13.7	9.6	6.0	9.4	---
	5	37.3	----	14.4	20.8	13.7	----	10.1	11.0	4.7	10.5	---
	6	----	----	15.2	22.2	18.0	----	11.2	8.2	3.6	8.8	---
III	7	----	----	13.7	14.4	20.2	----	14.3	15.2	5.6	5.1	---
	8	----	----	9.2	15.2	20.4	----	7.6	12.9	4.5	4.0	---
	9	----	----	5.9	16.3	21.0	----	9.4	~~8~~8.3	5.5	6.4	---
I-Average		31.6	23.1	18.6	21.4	15.2	13.0	13.0	14.0	4.0	18.4	5.5
II-Average		42.7	32.1	15.6	20.9	16.3	----	11.7	9.6	4.8	9.9	---
III-Average		----	----	13.7	15.3	20.5	----	10.4	12.1	5.2	5.2	---
Average for all the fields.		37.2	27.6	16.0	19.2	17.3	13.0	11.7	11 .9	4.7	11.2	5.6

Table VIII - The moisture equivalents of the foot sections.

Area	Depth foot	Silt loams		Loams			Fine sandy loams			Merrimac fine sand	Loamy fine sands	
		Clyde	Hemstead	Miami	Merrimac	Gloucester	Hemstead	Miami	Gloucester		Merrimac	Hinckley
I	0-½	30.7	24.0	21.0	20.5	13.1	14.9	12.3	13.5	3.6	7.1	5.3
	2	26.8	23.1	21.2	22.1	14.1	7.2	17.4	13.8	2.9	3.8	2.5
	3	26.2	23.8	19.7	13.9	16.1	10.1	20.0	14.8	2.5	3.3	2.2
II	0-½	37.3	32.1	14.4	19.7	17.3	12.5[a]	13.7	9.6	6.0	9.4	---
	2	19.9	24.1	15.4	14.6	19.7	9.2[a]	12.2	7.1	3.8	5.0	---
	3	19.3	24.1	18.9		16.6	9.9[a]		10.4	3.2	3.6	---
III	0-½	----	----	13.7	14.4	21.0	----	14.3	15.2	5.6	4.0	---
	2	----	----	13.9	19.0	20.3	----	13.4	9.1	3.0	3.0	---
	3	----	----	16.5	22.6	20.9	----	13.8	10.9	2.5	2.5	---
Av. for	0-½	34.0	28.1	16.4	18.2	17.1	13.7	13.4	12.8	5.1	6.8	5.3
Av. for	2	23.4	23.6	16.8	18.6	18.0	8.2	14.3	10.0	3.2	3.9	2.5
Av. for	3	22.8	24.0	18.4	18.3	17.9	10.0	16.9	12.0	2.7	3.1	2.2

(a) These sections are from a second field in area I.

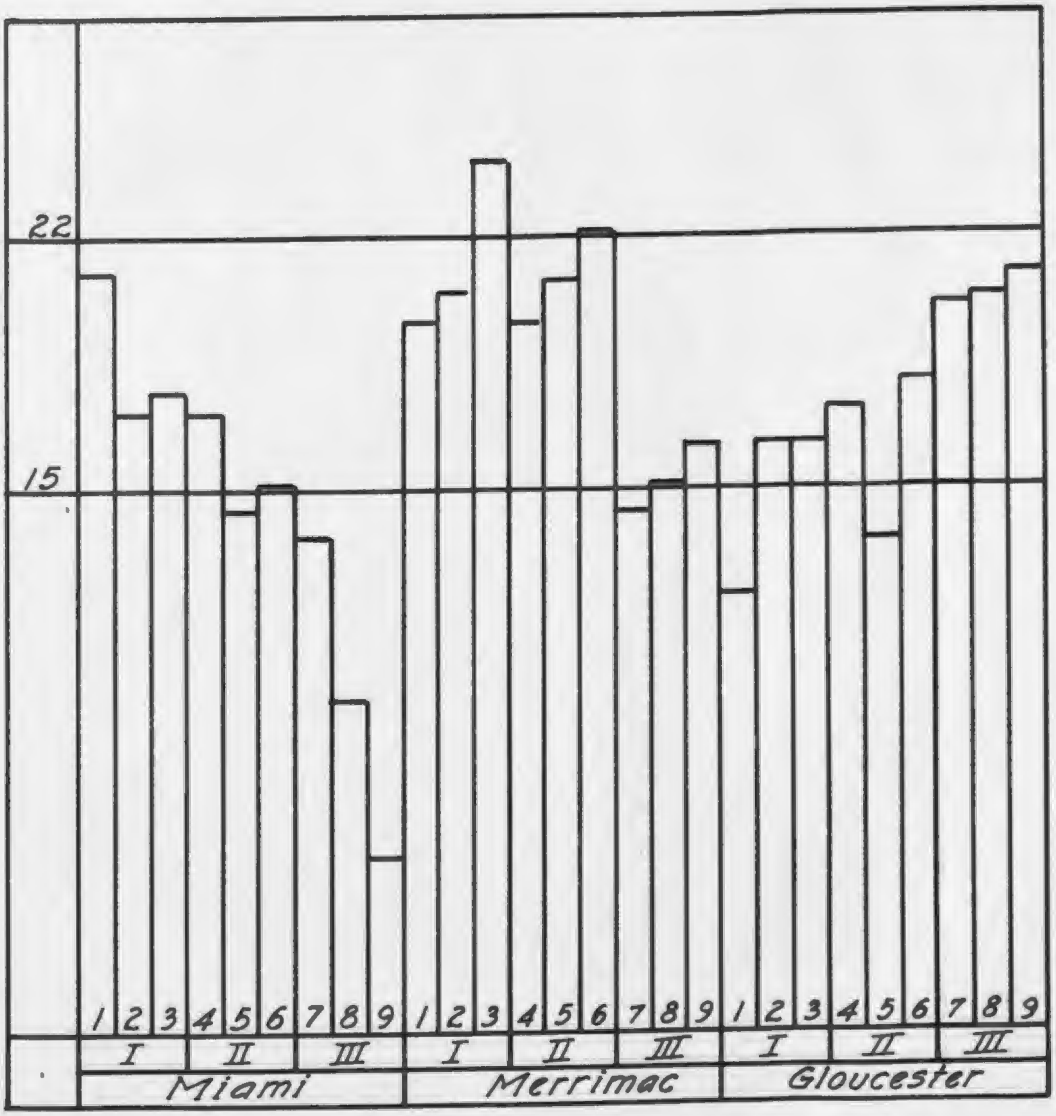
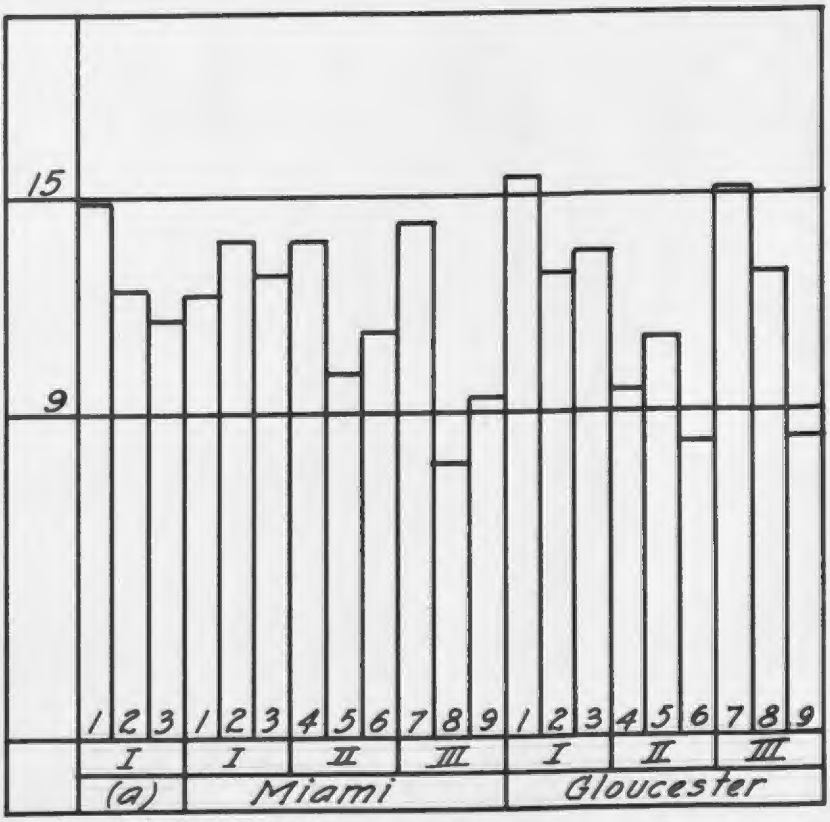
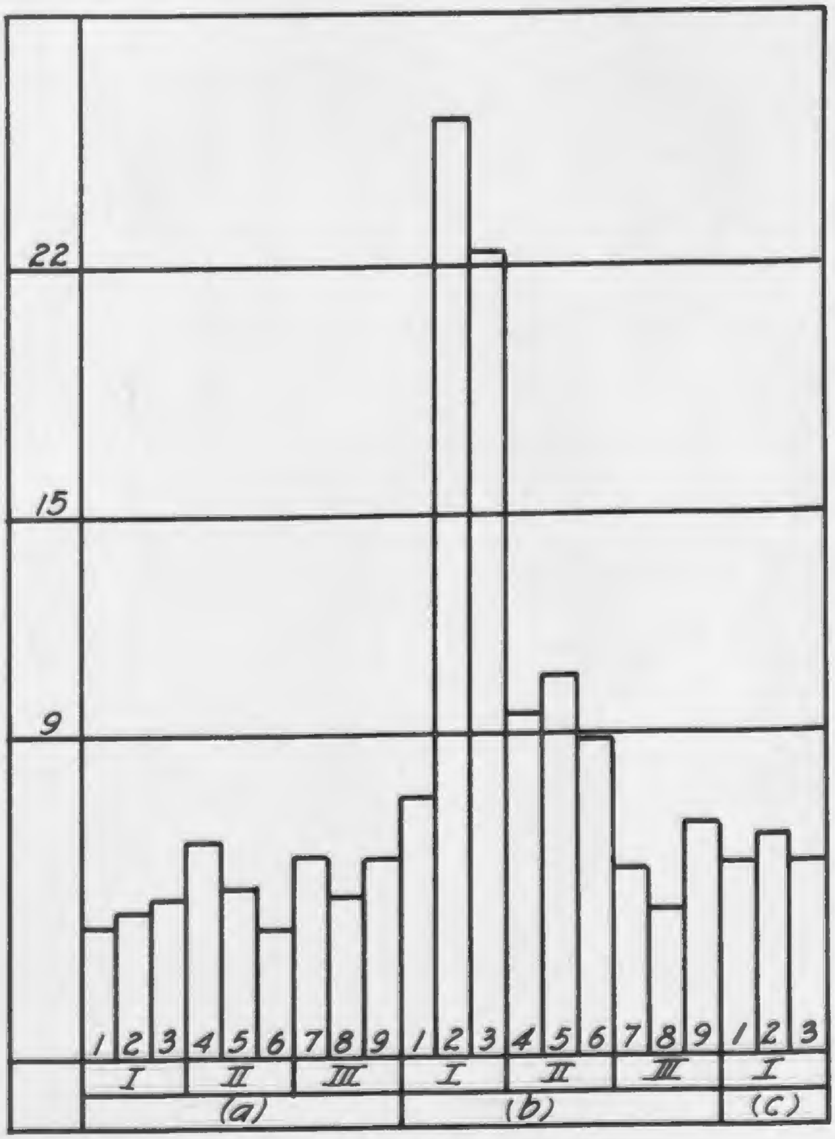


Fig. 5. The moisture equivalents of the loams.



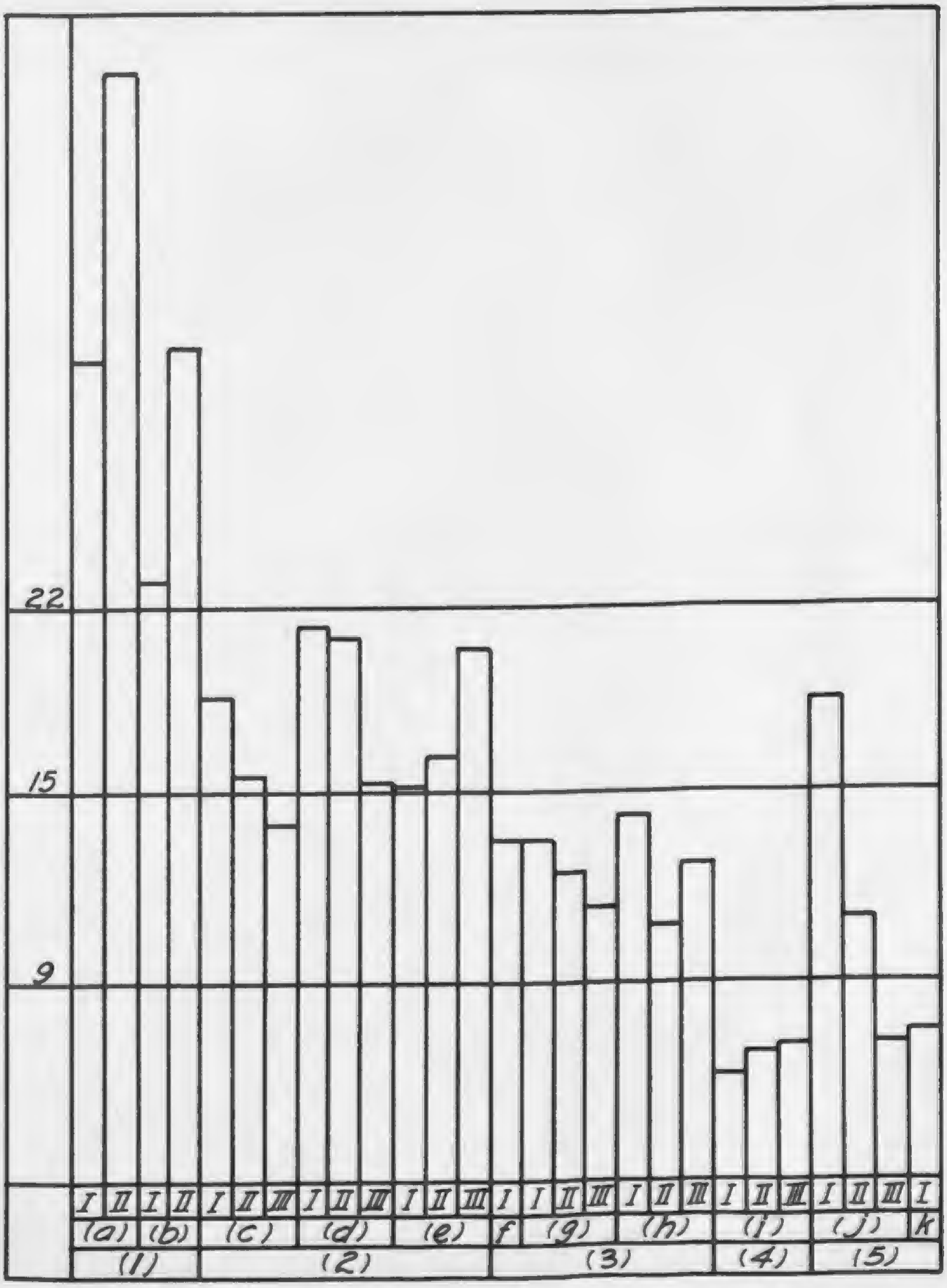
(a) Hempstead.

Fig. 6. The moisture equivalents of the fine sandy loams.



(a) Merrimac fine sand.
(b) Merrimac loamy fine sand.
(c) Hinckley loamy fine sand.

Fig. 7. The moisture equivalents of the fine sands and loamy fine sands.



(1) Silt loams, (a) Clyde. (b) Hempstead.
(2) Loams, (c) Miami. (d) Merrimac. (e) Gloucester.
(3) Fine sandy loams, (f) Hempstead. (g) Miami. (h) Gloucester.
(4) Fine sands, (i) Merrimac.
(5) Loamy fine sands, (j) Merrimac. (k) Hinckley.

Fig. 8. The moisture equivalents of the different areas.

been mapped as loams would fall without that class, while two that have been mapped as fine sandy loams would fall within it. If a fine sandy loam were to be defined as one with a moisture equivalent between 9.0 and 15.0, then five fields would fall without that class, while five mapped as loams, and two as loamy fine sands, would be included. Hempstead fine sandy loam would not be excluded as it would be if the soils were mapped according to the hygroscopic coefficients.

DEFINITION OF SOIL TYPES ON BASIS OF PHYSICAL CONSTANTS.

The relations of the hygroscopic coefficient and the moisture equivalent to soil classes have been summarised in Table IX. Without any intention to establish limits for soils in general, but simply as an arbitrary means of interpretation of the data here given, the following definitions of soil classes are proposed: -

1. Silt loams - Soils with hygroscopic coefficients between 7.5 and 21.0, or moisture equivalents between 22.0 and 50.0.

2. Loams - Soils with hygroscopic coefficients between 4.0 and 7.5, or moisture equivalents between 15.0 and 22.0.

3. Fine sandy loams - Soils with hygroscopic coefficients between 2.5 and 4.0, or moisture equivalents between 9.0 and 15.0.

4. Fine sands - Soils with hygroscopic coefficients below 2.5, or moisture equivalents below 9.0.

Classified on this basis, as shown in Table IX, 52 out of the 76 soils, when either the hygroscopic coefficient or the moisture equivalent is used, are true to the classification made on the usual basis. That the number should be the same for both constants is just what one should expect if the relation of moisture equivalent to hygroscopic coefficient were a constant. If we

Table IX - A summary of the relation of hygroscopic coefficient and moisture equivalent to soil class.

Soil Class	No. of Samples	No. true to type	Classified as SL	Classified as L	Classified as FSL	Classified as FS	Classified as LFS	These classes are included SL	These classes are included L	These classes are included FSL	These classes are included FS	These classes are included LFS
THE HYGROSCOPIC COEFFICIENT												
Silt loams (SL)	9	9										
Loams (L)	25	20			5					6		3
Fine sandy loams (FSL)	21	14		6		1			5			3
Fine sands (FS)	9	9								1		6
Loamy fine sands (LFS)	12	*		3	3	6						
Total *	76	52										
THE MOISTURE EQUIVALENT												
Silt Loams	9	9							2			2
Loams	25	18	2		5					2		
Fine sandy loams	21	16		2		3			5			2
Fine sands	9	9								3		8
Loamy fine sands	12	*	2		2	8						
Total *	76	52										

* A definition of loamy fine sand on the basis of these constants has not been made.

exclude the loamy fine sands, for which no definition is proposed, 52 out of 64, or about 80 per cent, are found true to type. The distribution of the others is not the same for both constants, a departure due to the lack of exact constancy in their relation. One may conclude that in general the soil class, as mapped in the field, may with equal accuracy, be estimated from either the hygroscopic coefficient or the moisture equivalent.

If the general scheme of this investigation were applied to numerous soil series in different parts of the country, all possible classes being included, the above conclusion might not be found to apply. In the present study, all of the soils involved have been divided among four groups, and hence the limits of a class are wide, and the chances of a soil falling without it much reduced. But if the soils were to be divided into twelve groups, corresponding to the 12 defined above (p. 7), very few of the soils defined on the usual basis would fall into the narrow classes prescribed by the moisture equivalents or the hygroscopic coefficients.

RELATION OF MOISTURE EQUIVALENT TO HYGROSCOPIC COEFFICIENT.

Briggs and Shantz (4), from a study of 17 soils differing widely in texture, found the ratio of moisture equivalent to hygroscopic coefficient to average 2.71, the maximum and minimum ratios being 3.11 and 2.22, respectively. Later Alway and Russel (2), working with 122 soils found a maximum of 3.29 and a minimum of 1.76. In the case of 72 samples from various levels of the surface foot of prairies they found maximum and minimum ratios of 3.29 and 2.33, and an average of 2.75.

As in the present study both the moisture equivalents and the hygroscopic coefficients were determined on the surface samples, the ratios are reported in Table X. These are far from constant, the minimum being 2.32, and the maximum 4.86. The former was in the case of a silt loam soil showing both the maximum hygroscopic coefficient and the maximum moisture equivalent, and being one of the highest in nitrogen, and hence, in organic matter. The average for all the soils of its type, 2.44, is the lowest shown by any of the types. The maximum ratio was found in the case of a Gloucester loam. The average for the soils of this type, 4.07, is the highest shown by any type. When the fields of each area are averaged, the uniformity within the type is very apparent. The ratio varies more between soils of the same class but of different series than between soils of the same series but of different classes. The ratios for the Hempstead soils are all of the same general order. Comparing series with series, the Gloucester soils show the highest ratios, then follow the Miami, to be succeeded by the Merrimac soils. This fully corroborates the conclusion of Alway and Russel (2, p. 842 and 845), that in any accurate study where use of this ratio is made to compute the one physical constant from the other, it will first be necessary to determine it for each soil type involved.

Mention has been made above (p. 19) of the comparatively low values of the hygroscopic coefficients for the loams and fine sandy loam soils. It will be seen that this causes the comparatively high values of their ME/HC ratios. In other words, if the moisture equivalents be considered normal, then the hygroscopic coefficients are abnormally low. Why this condition should exist is not evident. Alway and Russel (2, p. 845), found that the effect of very large quantities of organic matter in general is to raise the ratio, because, while this has little effect upon the hygroscopic coefficient, it has a marked effect upon the moisture equivalent.

Table X - The ratio of the moisture equivalent to the hygroscopic coefficient in the case of the surface samples.

Area	Field	Silt loams		Loams			Fine sandy loams			Merrimac	Loamy fine sands	
		Clyde	Hemstead	Miami	Merrimac	Gloucester	Hemstead	Miami	Gloucester	fine sand	Merrimac	Hinckley
I	1	2.74	3.08	4.12	3.08	3.64	2.75	3.62	3.30	2.66	3.22	
	2	2.42	2.92	3.80	3.31	4.40	2.91	4.06	3.80	2.79	4.33	
	3	2.44	2.91	3.69	3.54	3.88	2.90	4.03	3.65	2.82	4.46	
II	4	2.32	2.86	3.98	3.08	4.12	----	2.49	3.56	3.11	2.85	----
	5	2.36	----	4.23	3.30	3.19	----	3.61	3.55	2.97	2.44	----
	6	----	----	3.38	3.00	4.09	----	4.48	3.73	2.55	3.04	----
III	7	----	----	3.61	3.79	4.21	----	3.25	4.00	2.81	2.50	----
	8	----	----	3.28	3.24	4.86	----	3.04	4.03	2.81	2.56	----
	9	----	----	3.91	3.79	4.28	----	3.35	3.32	3.00	2.56	----
I-Average		2.54	2.97	3.87	3.31	3.97	2.79	3.90	3.58	2.76	4.00	
II-Average		2.34	2.86	3.86	3.13	3.80	----	3.53	3.61	2.88	2.78	----
III-Average		----	----	3.61	3.61	4.45	----	3.21	3.78	2.87	2.54	----
Average for all the fields.		2.44	2.92	3.78	3.35	4.07	2.79	3.55	3.66	2.84	3.11	

RELATION OF NITROGEN CONTENT TO SOIL CLASS.

The nitrogen content of the surface samples was determined by the modified Gunning Method in the usual manner. The analyses were made in duplicate, these being expected to agree within .004 per cent, and a blank was run with each charge. The data are presented in Table XI.

The range in nitrogen content of these soils is very wide, ranging from 1.030 to 0.030 per cent, and no strict relationship is shown between nitrogen content and soil class. In general the silt loams are the richest in nitrogen, these being followed in order by the loams, the fine sandy loams, the loamy fine sands, and the fine sands. No limits within which all of the soils fall can be set for any class, with each a number of samples from other classes falling within any limits so placed. Thus if the lower limit for silt loams be set at .195, then one sample of loam, having a nitrogen content of .201 falls within that class. If the limits for loams be put at .090 and .195, then out of 25 soils, five fall without that limit while eleven soils of other classes fall within. If the limits for fine sandy loams be made .060 and .090, then out of 21 soils, nine would fall without the class, and eleven soils of other classes would fall within. As in the case of the physical constants, the loamy fine sand class appears undefinable. The nitrogen content of the three fields of any one area show but little uniformity, one soil in each area standing apart from the other two which agree satisfactorily. However, in a general way, the magnitude of the nitrogen content permits one to recognize the class to which an area belongs, but on the basis of the nitrogen content alone, one might classify the second and third areas of Miami loam with the fine sandy loams, and the Hempstead

Table XI - The nitrogen content of the surface samples.

		Silt loams		Loams			Fine sandy loams			Merrimac	Loamy fine sands	
Area	Field	Clyde	Hemstead	Miami	Merrimac	Gloucester	Hemstead	Miami	Gloucester	fine sand	Merrimac	Hinckley
		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
I	1	.398	.240	.125	.166	.090	.163	.075	.162	.030	.068	.063
	2	.298	.219	.114	.157	.088	.118	.080	.084	.035	.156	.080
	3	.500	.195	.129	.121	.112	.114	.070	.085	.047	.147	.086
II	4	1.030	.343	.115	.158	.099	----	.167	.060	.055	.095	----
	5	.605	----	.084	.154	.105	----	.075	.079	.041	.118	----
	6	----	----	.079	.201	.119	----	.057	.044	.036	.075	----
III	7	----	----	.087	.091	.121	----	.153	.093	.063	.051	----
	8	----	----	.076	.095	.119	----	.068	.082	.057	.034	----
	9	----	----	.058	.099	.137	----	.081	.071	.055	.072	----
I-Average		.598	.218	.123	.148	.097	.132	.075	.110	.037	.124	.076
II-Average		.818	.343	.093	.171	.108	----	.100	.061	.044	.096	----
III-Average		----	----	.087	.095	.126	----	.099	.082	.058	.052	----
Average for all the fields.		.708	.280	.101	.138	.110	.132	.091	.084	.046	.091	.076

fine sandy loam with the loams.

RELATION OF NITROGEN CONTENT TO HYGROSCOPIC COEFFICIENT.

If the surface soils be grouped, not on the basis of the field survey but according to their physical constants, the relation of nitrogen content to texture is more apparent. In Table XII, the soils have been arranged in order of descending values of their nitrogen content, without any reference to their type names. To further facilitate a comparison, they have been brought into fourteen groups, the soils within a group having either similar nitrogen values, or similar hygroscopic coefficients. It will be seen that all of the silt loams fall in the first two groups, and all of the fine sands in the last three, while representatives of the others are found in practically every group.

The table presents some interesting relations between nitrogen content and hygroscopic coefficient. In Groups 3, 4, 6, 8, 9, 10, 11 and 12, the nitrogen values are close enough to be considered duplicates for the same sample. Almost the same is true for the hygroscopic coefficients.

The relation of nitrogen content to moisture equivalent is not so marked. In a number of the groups, triplicates can be picked out whose moisture equivalents and content of nitrogen are close enough to be duplicates, as in groups 4, 6, 8 and 9. Considering only the averages for the different groups, it is true that, with one exception, the nitrogen content decreases with the moisture equivalent and the hygroscopic coefficient.

The relation of the nitrogen content to the physical constants may be better shown in the form of ratios. The ratio of moisture equivalent to nitrogen (ME/N) and the ratio of hygroscopic coefficient to nitrogen (HC/N)

Table XII - The relation of the nitrogen content to the moisture equivalent and to the hygroscopic coefficient.

Group	Series	Class	Nitrogen	Moisture equivalent	Hygroscopic coefficient	ME / N	3(HC/N)
			per cent				
1	C	Sl	1.030	48.0	20.7	47	60
	C	Sl	.605	37.3	15.8	62	78
	C	Sl	.500	30.8	12.6	62	76
	C	Sl	.398	30.7	11.2	77	84
	He	Sl	.343	32.1	11.2	94	98
Average			.575	35.8	14.3	62	75
2	C	Sl	.298	33.2	13.7	111	138
	He	Sl	.240	24.0	7.8	100	98
	He	Sl	.219	22.8	7.8	109	107
	Me	L	.201	22.2	7.4	110	123
	He	Sl	.195	22.4	7.7	115	118
Average			.231	24.9	8.9	108	116
3	Mi	Fsl	.167	13.7	5.5	82	99
	Me	L	.166	19.7	6.4	119	116
	He	Fsl	.163	14.9	5.4	91	99
	G	Fsl	.162	15.5	4.7	96	87
Average			.165	16.0	5.5	97	100
4	Me	L	.158	19.7	6.4	125	122
	Me	L	.157	20.5	6.2	131	118
	Me	Lfs	.156	26.0	6.0	167	115
	Me	L	.154	20.8	6.3	135	123
Average			.156	21.8	6.2	140	119
5	Mi	Fsl	.153	14.3	4.4	93	86
	Me	Lfs	.147	22.3	5.0	152	102
	G	L	.137	21.0	4.9	153	107
	Mi	L	.129	17.7	4.8	137	112
	Mi	L	.125	21.0	5.1	168	122
	Me	L	.121	24.1	6.8	199	169
	G	L	.121	20.2	4.8	167	119
Average			.133	20.1	5.1	151	115

Table XII - Continued

Group	Series	Class	Nitrogen	Moisture equivalent	Hygroscopic coefficient	ME / N	3(HC/N)
				per cent			
6	G	L	.119	20.4	4.2	171	106
	G	L	.119	18.0	4.4	151	111
	He	Fsl	.118	12.5	4.3	106	109
	Me	Lfs	.118	10.5	4.3	89	109
	Mi	L	.115	17.1	4.3	149	112
	Mi	L	.114	17.1	4.5	150	118
<u>Average</u>			.117	15.9	4.3	136	111
7	He	Fsl	.114	11.6	4.0	102	105
	G	L	.112	16.3	4.2	145	112
	G	L	.105	13.7	4.3	131	123
	G	L	.099	17.3	4.2	175	127
	Me	L	.099	16.3	4.3	165	130
	Me	L	.095	15.2	4.7	160	148
<u>Average</u>			.104	15.1	4.3	145	124
8	Me	Lfs	.095	9.4	3.3	98	104
	G	Fsl	.093	15.2	3.8	163	123
	Me	L	.091	14.4	3.8	158	125
	G	L	.090	13.1	3.6	146	120
	G	L	.088	16.3	3.7	185	126
	Mi	L	.087	13.7	3.8	158	131
	Hi	Lfs	.086	5.3	1.9	62	66
	G	Fsl	.085	13.5	3.7	159	131
<u>Average</u>			.089	12.6	3.5	142	118
9	Mi	L	.084	14.4	3.4	171	122
	G	Fsl	.084	12.9	3.4	154	122
	G	Fsl	.082	12.9	3.2	157	117
	Mi	Fsl	.081	9.4	2.8	116	104
	Mi	Fsl	.080	13.8	3.4	172	128
	Hi	Lfs	.080	6.0	2.3	75	86
	Mi	L	.079	15.2	4.5	192	171
<u>Average</u>			.081	12.1	3.3	149	121
10	G	Fsl	.079	11.0	3.1	139	118
	Mi	L	.076	9.2	2.8	121	110
	Mi	Fsl	.075	12.3	3.4	164	136
	Mi	Fsl	.085	10.1	2.8	135	112
	Me	Lfs	.075	8.8	2.9	117	116
<u>Average</u>			.076	10.3	3.0	136	118

Table XII - Continued

Group	Series	Class	Nitrogen	Moisture equivalent	Hygroscopic coefficient	ME / N	3(HC / N
			Per cent				
11	Me	Lfs	.072	6.4	2.5	89	104
	G	Fsl	.071	8.3	2.5	117	106
	Mi	Fsl	.070	12.9	3.2	184	137
	Me	Lfs	.068	7.1	2.2	104	97
Average			.070	8.7	2.6	124	111
12	Me	Fs	.063	5.6	2.0	89	95
	Hi	Lfs	.063	5.3	1.7	84	83
	Mi	Fsl	.062	7.6	2.5	123	121
	G	Fsl	.060	9.6	2.7	160	135
	Mi	L	.058	5.9	2.1	102	109
	Mi	Fsl	.057	11.2	2.5	197	132
Average			.061	7.5	2.4	123	113
13	Me	Fs	.057	4.5	1.6	79	84
	Me	Fs	.055	6.0	1.9	109	105
	Me	Fs	.055	5.5	1.8	100	100
	Me	Lfs	.051	5.1	2.0	100	120
	Me	Fs	.047	4.4	1.6	94	100
	G	Fsl	.044	8.2	2.2	186	150
Average			.052	5.6	1.9	108	117
14	Me	Fs	.041	4.7	1.6	115	116
	Me	Fs	.036	3.6	1.4	100	117
	Me	Fs	.035	4.1	1.5	117	126
	Me	Lfs	.034	4.0	1.6	118	138
	Me	Fs	.030	3.6	1.3	120	135
Average			.035	4.0	1.5	114	125

Legend - Series, Clyde (C), Hempstead (He), Miami (Mi), Merrimac (Me),

Gloucester (G), Hinckley (Hi).

Classes, Silt loam (Sl), Loam (L), Fine sandy loam (Fsl),

Fine sand (Fs), Loamy fine sand (Lfs).

have been calculated, the latter being multiplied by 3 to make the values directly comparable with the ME/N ratio. This also makes percentage variations more conspicuous, as the values then lie around 100. In the case of the ME/N ratios it is seen that about half of the soils in each group give ratios which are fairly similar within the group but not of the same order from group to group. Omitting groups 1, 2, 3, and 14, the average ratios run from 114 to 152, a variation of 33 per cent. So, on the basis of both individual soils and soils by groups, it appears that the nitrogen content is not a strict linear function of the moisture equivalent. Neither has any other relationship been found by means of which the nitrogen content can be estimated from the moisture equivalent. This conclusion is directly contrary to that derived above from the computation on the data of Swanson on Kansas soils. His were prairie soils while these are from areas originally in forest.

In the case of the hygroscopic coefficients, however, the nitrogen content is a linear function of the hygroscopic coefficient. Leaving out the first and third groups, the averages run from 111 to 132, a variation of only 20 per cent, and the variation in each group becomes much narrower when a few exceptional values are omitted from the average. However, in both groups 1 and 3 the nitrogen content is high in proportion to the hygroscopic coefficient as well as to the moisture equivalent.

The dependence of the nitrogen content upon the hygroscopic coefficient is still better shown in Table XIII in which the ratios HC/N for the individual soils are shown. Excepting two types, the Clyde silt loam and the Hinckley loamy fine sand, the ratios range from 26 to 57, with an average of 38.4. Thirty five of them lie between the limits 37 and 43,

Table XIII - Ratio of hygroscopic coefficient to nitrogen content in surface samples.

Area	Field	Silt loams		Loams			Find sandy loams			Merrimac fine sand	Loamy fine sands	
		Clyde	Hemstead	Miami	Merrimac	Gloucester	Hemstead	Miami	Gloucester		Merrimac	Hinckley
I	1	28	33	41	39	40	33	45	29	45	32	28
	2	46	36	39	40	42	36	43	40	42	38	29
	3	25	40	37	56	37	35	46	44	33	34	22
II	4	20	33	37	41	42	--	33	45	35	35	--
	5	26	--	41	41	41	--	37	39	39	36	--
	6	--	--	57	37	40	--	44	50	39	39	--
III	7	--	--	44	42	40	--	29	41	32	40	--
	8	--	--	37	49	35	--	40	39	28	46	--
	9	--	--	36	43	36	--	35	35	33	35	--
I-Average		33	36	39	44	39	35	44	35	39	35	26
II-Average		23	33	44	39	40	--	36	44	37	36	--
III-Average		--	--	39	45	36	--	35	39	31	38	--
Average for all the fields.		28	34	40	42	38	35	38	39	36	36	26

with an average of 39.8. The other values are distributed on both sides of these limits and average 37.3. These exceptional values are not confined to any one type except those of the Clyde and Hinckley series, whose nitrogen contents appear to be higher in proportion to the texture than in any other soils, in one of which the accumulation of organic matter has been favored by excess of moisture and in the other by the lack of moisture.

It must not be concluded that the nitrogen content of a soil can be closely calculated by dividing the hygroscopic coefficient by 38.4 or by another number. If there be a general relation between nitrogen and hygroscopic coefficient, the determination of these values may give valuable information about a soil. Thus, if the nitrogen be found to be lower than that indicated by the formula, the soil is to be judged as relatively low in nitrogen, and if it is higher than the calculated, it is in a high state of fertility with respect to that element. In devising any such a formula, it is, of course, to be recognized that since the nitrogen content decreases with the depth, a different formula would be required for each successive section sampled.

RELATION OF SOIL REACTION TO TEXTURE.

The acidity of the surface samples and of the foot sections of the subsoil was determined by the Truog method (18). The data for the surface samples are shown in Table XIV, and those for the subsoils in Table XV. Since samples from the second and third feet were taken in only one field of each area, the acidity as well as the moisture equivalents of two 0-½ foot sections are those for the one field only, rather than averages for the three.

Table XIV - Acidity of the surface samples by the Truog method.
(0= neutral; 1= very slight; 2= slight; 3= medium; 4= strong)

Area	Field	Silt loams		Loams			Fine sandy loams			Merrimac fine sand	Loamy fine sands	
		Clyde	Hemstead	Miami	Merrimac	Gloucester	Hemstead	Miami	Gloucester		Merrimac	Hinckley
I	1	0	2	2	2	2	4	1	2	2	2	0
	2	0	2	1	3	1	3	1	2	2	3	0
	3	0	2	2	2	1	2	1	2	2	2	2
II	4	0	3	1	2	1	-	2	2	2	2	-
	5	0	-	1	2	1	-	1	2	2	2	-
	6	-	-	0	2	2	-	1	2	2	2	-
III	7	-	-	1	2	2	-	1	2	2	2	-
	8	-	-	2	2	2	-	1	1	2	2	-
	9	-	-	1	3	3	-	2	2	2	2	-

Table XV. Acidity of the foot sections by the Truog method.

Area	Depth	Silt loams		Loams			Fine sandy loams			Merrimac fine sand	Loamy fine sands	
		Clyde	Hemstead	Miami	Merrimac	Gloucester	Hemstead	Miami	Gloucester		Merrimac	Hinckley
	Foot.											
I	0-½	0	2	2	2	2	4	1	2	2	2	0
	2	0	0	1	0	2	1	2	1	0	0	0
	3	0	0	1	0	2	1	2	1	0	0	0
II	0-½	0	3	1	2	1	3[a]	2	2	2	2	--
	2	0	4	1	1	1	1	2	1	0	0	--
	3	0	3	1		1	1		1	0	0	--
III	0-½	--	--	1	2	3	--	1	2	2	2	--
	2	--	--	1	1	1	--	0	1	0	0	--
	3	--	--	1	1	1	--	0	0	0	0	--

(1 - Very slight; 2 - slight; 3 - medium; 4 - strong; 0 - neutral.)

(a) These sections are from a second field in area I.

Of the 78 samples, 8 are neutral, 17 very slightly acid, 48 slightly acid, 4 of medium acidity and 1 strongly acid. Of the 54 subsoil samples from the second and third feet, 25 are neutral, 22 very slightly acid, 5 slightly acid, 1 of medium acidity, and 1 strongly acid. The Clyde soils, which occupy but 1.1 per cent of the area of this county, are the only strictly neutral soils. There is no relation between acidity and soil class, acidity appearing to be a characteristic of the series, rather than of the class. Ranking the surface soils according to decreasing acidities, the series run:

Hempstead, Merrimac, Gloucester, Miami, Hinckley, Clyde.

The subsoils rank: -

Hempstead, Gloucester, Miami, Merrimac, Hinckley, Clyde.

The data might suggest that the explanation of the lower acidity of the Merrimac subsoils is to be found in their texture, (Table VIII), in the Merrimac series the subsoils being characteristically coarser than the surface soils. This openness of texture and consequent improvement in drainage is accompanied by a lowering of the acidity of the subsoil, if not of the surface, a condition quite contrary to what was to be expected. In Area III of Merrimac loam, the moisture equivalents of the subsoil sections are higher than those for the surface material, and the same sections are acid. The rule that the open subsoil is accompanied by a lowering in the acidity holds for the Hempstead fine sandy loam and for Area III of Gloucester fine sandy loam. The subsoil sections of Area III of Miami fine sandy loam are neutral, but not coarser in texture than the surface. The original high lime content of the Gray Drift does not appear to have any present-day effect upon the reaction of the Miami soils, for they are not markedly less acid than the Gloucester soils which have been formed from the Red Drift derived from crystalline and sandstone rocks.

SUMMARY.

The chemical analyses of 38 Kansas soils, representing 8 soil classes, reported by Swanson, and the mechanical analyses of the same types reported by the U. S. Bureau of Soils, have been brought together, and the moisture equivalents computed. The physical constants, nitrogen content and reaction of 132 samples from Ramsey County have been determined, the soils representing 11 types and 5 classes.

The class to which a soil belongs may be judged, and this with equal accuracy from the determination of either the hygroscopic coefficient or the moisture equivalent. A classification based upon either of these constants would not be identical with that made by the experienced field man upon the usual basis, but would correspond to that based upon actual mechanical analyses. The use of the moisture equivalent would probably result in a lowering of the number of recognizable soil types, possibly, however, without reducing the scientific or practical value of the soil survey.

There appears a natural tendency toward a linear relationship of physical constant to nitrogen content in the case of both the Kansas and the Minnesota soils. In the latter the nitrogen content is more closely related to the hygroscopic coefficient than to the moisture equivalent, due to the lack of constancy in the inter-relationship of these two values.

No definite relationship is shown between the reaction of the soil and the soil class, the reaction appearing to be a characteristic of the series rather than of the texture of the surface stratum.

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