MODELS FOR PREDICTING TOBACCO YIELD AND QUALITY FROM PHYSICAL SITE CHARACTERISTICS

By

WILLIAM L. MYKES

A Thesis
Submitted to the Department of Geography
in Partial Fulfilment of the Requirements
for the Degree
Bachelor of Arts

McMaster University
May 1968

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation for the advice and supervision received from Professor L. G. Reeds in the early stages of the development of this paper. Particularly important was the allowance made for a freedom of experimentation in methods of gathering data. Thanks must be given to Professor W. C. Found who made helpful suggestions in the specialized area of the handling of the statistical methods, and ultimately greatly assisted in the articulation of results. Thanks must also be given to Professor T. H. Lane of the Soil Science Department in the Ontario Agricultural College for offering access to his data and freely offering his time for the interpretation of the data. Mention must also be made of the many graduate students in the McMaster Geography Department who were approachable, and readily offered advice on various aspects of the paper.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

INTRODUCTION

From the beginnings of modern geography, about 1750, geographers have been concerned with illustrating the relationships between natural environment and man's spatial activity. This interest has motivated my study. The specific relationship with which I am concerned is the relationship between aspects of the physical environment and tobacco yield and quality.

Two townships, Charlotteville and Windham, were chosen as the study area since they represent a cross section of a concentrated tobacco growing area in Southern Ontario. Within the bounds of this study area, the first step was to examine how accurately various classifications measure pertinent physical factors of locations or sites, and secondly, to consider whether it could be illustrated that this classification correlates with actual yield and quality.

One tobacco soil capability classification was available, that was developed by the Ontario Agricultural College; but on testing, it was found to be inconsistent as a predictive model. Accordingly, this paper sets out to supplement the existing classification system to make it more predictive of yield and quality. Additional variables are analyzed with statistical multivariate techniques to determine how well they predict yield and quality.

In the following pages, the existing classification system is described and then tested by linear regression, simple and multiple. The soil type variable is weighted on the basis of evidence in papers which suggests the influence of different soil types on tobacco growth. It is then tested against actual yields and quality. Another variable, the depths of the cultivated layer, 7 to 14 inches, suggested that a detailed examination of the variable might prove interesting.

Two hypotheses are examined in this paper, first, the hypothesis that the original classification is predictive of yield and quality, and second, that two other physical factors, soil type and the depth of the cultivated layer* are predictive of yield and quality. To simplify the presentation, the paper is divided into three sections; the data sources and selection of data, the tests, and the conclusions. Thus reference is made in Chapter I to the unsuccessful predictive ability of the original classification system which lead to the examination of additional data, although the test of this classification system is not described until Chapter II.

Chapter I describes all the data sources, the selection of the data, and preparation of the data for testing. The original classification system is described, and the physical factors which comprise it, texture, drainage and topography, are considered in detail. After the test of this classification system (as described in Chapter II), the additional variables, soil type and the depth of the cultivated layer are selected, since the original classification system proved inconsistent in its prediction of yields.

---

* The depth of the cultivated layer refers to the depth to which the soil is disturbed through cultivation. Tobacco farmers normally cultivate to about 7 inches but this disturbed layer was found to be as deep as 16 inches (see Table 9 and Figure 3).

Three different weightings of soil types are formulated for testing, and finally, the depth of the cultivated layer measurements are considered.

In Chapter II, all the tests are described. First the physical factors are compared with yield and quality data using linear simple regression analysis, and secondly, the most important variables are selected by linear multiple regression as being best predictive of yield and quality. The variables tested are those comprising the original classification system, the three different weightings of soil types, and the depth of the cultivated layer.

The final chapter contains a summary and conclusions, and in addition, some recommendations based on the results and conclusions of this paper.

CHAPTER I

THE DATA

THE SETTING

The intention of this study is to examine relationships between aspects of the physical environment and tobacco yield and quality. With this in mind a study area was determined, and sources of data sought. Contact was made with Dr. T.H. Lane, of the Soils Science Department of the Ontario Agricultural College, who had developed a system of classification for tobacco soils. In doing so, he collected data from 325 sample farms across Ontario using a stratified random sample. With this data made available by Lane, a study area was selected to encompass a minimum of 30 sampled farms. Besides containing the minimum 30 sample farms, it was decided to include a cross section of a concentrated tobacco growing area. The section selected comprised the two townships of Windham and Charlotteville which are located in Norfolk County, the most productive tobacco growing county in Ontario (Figure 1). Forty-one sampled farms are contained in the study area. Their locations are shown in Figure 2.

THE HYPOTHESES

Two hypotheses are examined. First is the hypothesis that Lane's classification system is predictive of yield and quality of

FIG. 1

SITE LOCATION

Windham and Charlotteville Townships

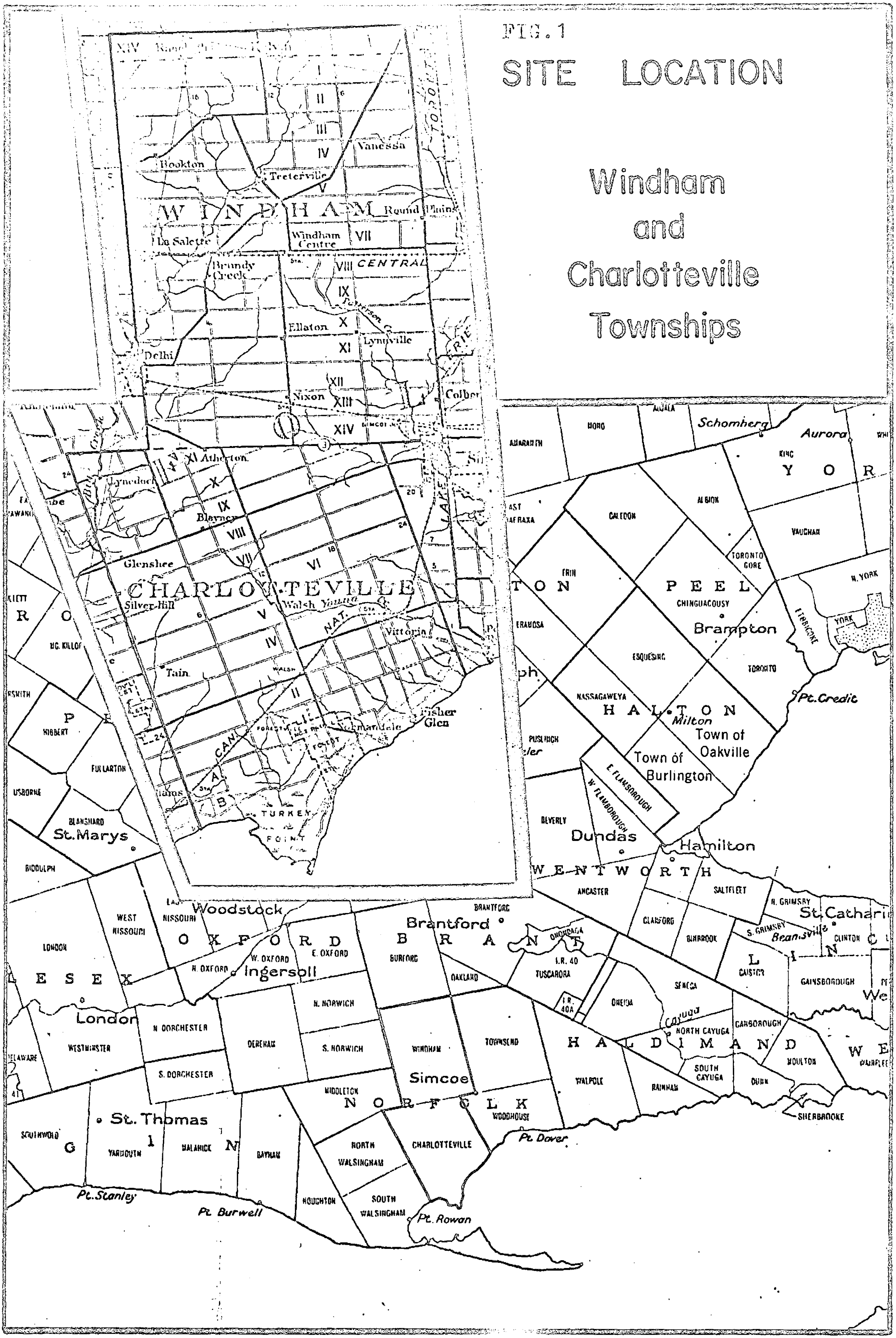
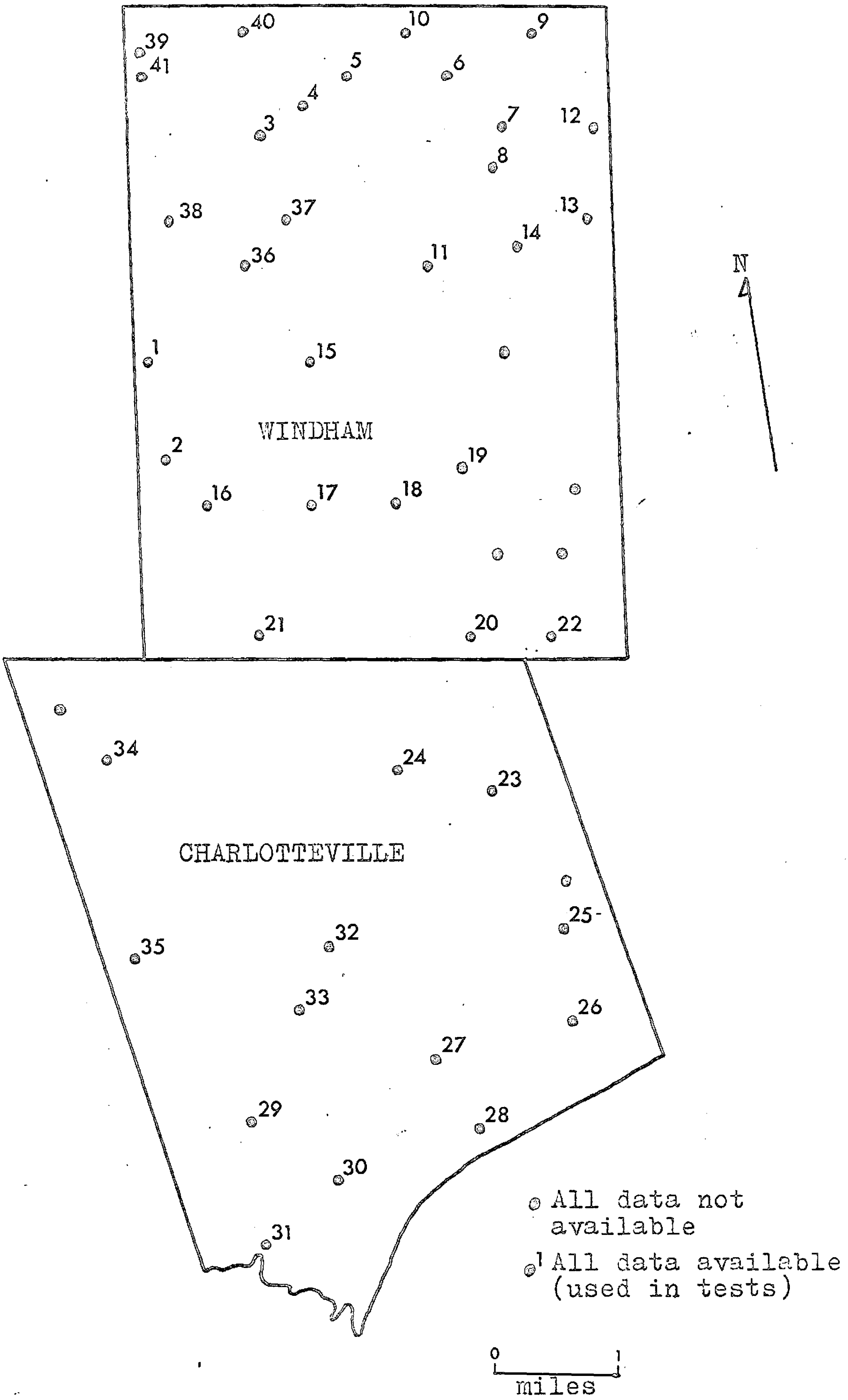


FIG.2 LOCATION OF SAMPLE FARMS IN THE STUDY AREA



tobacco. Second is the hypothesis that other physical factors are even more predictive of yield and quality. For the testing of these hypotheses, Lane provides a considerable amount of data on physical soil characteristics in the form shown on Sample Forms I, II, and III in Appendix 1. Also made available are actual yield data for the 41 sample farms for 1962, and quality data for the same season. Yield data for 1960 are available for 39 sampled farms. The selection and preparation of the data for the testing of the hypotheses are described in the following sections.

LANE'S CLASSIFICATION SYSTEM

In his classification system, Lane uses four factors assessed and weighted mathematically for each farm site. The factors are soil texture, drainage, topography, and erosion. Although he anticipated finding evidence of erosion, none was found in his samples. These factors are evaluated numerically as on Forms I and III (Appendix 1), and they are added together and subtracted from 100 so that the individual farm site falls into one of the six categories shown on Form II (Appendix 1). For the analysis of this classification system, the data for each of the factors, texture, drainage, and topography, are tested against the yield and quality data. This is done as a test of the weighting of each of these factors. These data are then tested as an aggregate figure against the yield and quality data.

In recording the data for each of the sample sites, Lane added an additional figure which indicated the amount of the area of the farm site that a particular physical disadvantage covered. For example, if a farm site had a topographic disadvantage, Lane would record the disadvantage according to the steepness of the slopes found on the farm. This could be either 15 or 30, and so on. However, on certain sections of the farm, there were no slope disadvantages. In this case, he would record the figure, either 15 or 30, and then in another section of his record (Appendix 1, Section C. 1.) he would indicate the percent of the farm site that was either free from the disadvantage, or had a different characteristic from that recorded. This was also indicated by an arrow on Form I (Appendix 1). The reason for this was that if 50 percent of a sample farm site contained a topography rated 15, and the remaining 50 percent contained a topography rated 30, the sample was not used by him. Although Lane did not use these percent figures in the ultimate classification, they are considered here as a more detailed description of the sample sites. Consequently, these data are employed in the analysis of the rating system. Also, the farm site samples which are divided by 50 percent, as shown above, are not rejected, instead, the figure 22.5 is derived by taking 50 percent of 15, and 50 percent of 30, and adding them together. This method of utilizing the percent figure is used for all Lane's data. These figures for the 41 samples (Appendix 2) are used in the linear regression analyses in Chapter II.

A check is made on the derivation of this data by using the circled figure and the arrow (representative of the percent figure) as shown on Sample Form II of Appendix 1. Here, the 50 percent figure is used to derive the figures 80 and 65 from the following example of classification:

I	II	III	IV	V	VI
100-90	85-75	70-60	55-45	40-30	25 or less

These figures are averaged to give 72.5. It was not felt necessary for the correlation analysis, which provided the check, to subtract this figure from 100. These data are shown in Appendix 2.

SOIL TYPE AS A CLASSIFICATION SYSTEM

The Soil Survey of Oxford County presents a rating of soils based on the characteristics of the soil and the appearance of crops growing on the soil, together with information supplied by farmers and officers from agricultural stations.[1] The rating for specified crops including tobacco has six categories: namely, good, good-fair, fair, fair-poor, poor, and very poor (see Table 1). For testing, these categories are numbered from 1 to 6.

The first problem in utilizing this rating is that although soil series are found to be the same for both Norfolk and Oxford

---

[1] Ontario Dept. of Agriculture. Soil Survey of Oxford County, Guelph, p 46.

TABLE 1

TABLE 4 - In the Oxford Soil Survey

*SOIL RATINGS FOR PRINCIPAL CROPS

SOIL RATINGS FOR

SOIL NAME	WINTER WHEAT		OATS		CORN		ALFALFA		TOBACCO		TURNIPS		CULTIVATED HAY		PASTURE		TREE-FRUITS APPLES		VEGETABLE CROPS, TOMATOES, PEAS, SWEET CORN	
	DR.	UND.	DR.	UND.	DR.	UND.	DR.	UND.	DR.	UND.	DR.	UND.	DR.	UND.	DR.	UND.	DR.	UND.	DR.	UND.
Bennington silt loam		G		G		G		G		VP		G-F		G		G		G-F		G
Berrien sandy loam	F-P	P	F	F-P	F-P	P	F	P	F	P	F	P	F	P	F	P	F-P	P	G-F	P
Bookton sandy loam		F-P		F-P		F-P		F		F		F		F		F		F-P		F
Bottom land		VP		P		P		P		VP		P		F		G-F		VP		P
Brady loamy sand	F	F-P	F	F-P	F	F-P	F	P	F	VP	P	VP	F	F-P	F	F-P	F	P	F	P
Brisbane sandy loam	F	F-P	F	F-P	F	F-P	F	P	F	VP	P	VP	F	F-P	F	F-P	F	P	F	P
Brookston clay loam	F	P	F	P	F	P	F	P	VP	VP	F	P	G-F	F	G-F	F		P	F	P
Brookston silt loam	F	P	F	P	F	P	F	P	VP	VP	F	P	G-F	F	G-F	F		P	F	P
Burford loam		G-F		G-F		G		G-F		F		F		G-F		G-F		G		G
Burford sandy loam		G-F		G-F		G		G-F		G-F		F		G-F		G-F		G		G
Crombie silt loam	F	P	G-F	F-P	G-F	P	F	VP	VP	VP	G-F	P	G-F	F	G-F	F	VP	VP	G-F	P
Donnybrook sandy loam		P		P		P		P		P		P		P		P		P		P
Embro silt loam	G-F	F	G	G-F	G	F	G-F	F	VP	VP	G	F	G	G-F	G	G-F	F	P	G	F
Fox loamy sand		P		P		P		P		G-F		P		P		P		F		P
Fox sandy loam		F		F		G-F		F		G		P		F		F		G		G-F
Fox fine sandy loam		F		F		G-F		F		G		P		F		F		G		G-F
Gilford sandy loam	F-P	VP	F	P	F	VP	P	VP	VP	VP	P	VP	F	P	F	P	P	VP	F	VP
Granby sandy loam	P	VP	F	P	F	VP	P	VP	VP	VP	P	VP	F	P	F	P	P	VP	F	VP
Guelph loam		G		G		G-F		G		P		G-F		G		G		G		G-F
Guelph silt loam		G		G		G-F		G		P		G-F		G		G		G		G-F
Honeywood silt loam		G		G		G-F		G		P		G-F		G		G		G		G-F
Honeywood-Guelph Complex		G		G		G-F		G		P		G-F		G		G		G		G-F
Huron clay loam		G		G		G		G-F		P		G-F		G-F		G-F		F		G-F
Huron silt loam		G		G		G		G		P		G-F		G		G		G-F		G-F
London loam	G-F	F	G	G-F	G	F	G-F	F	VP	VP	G	F	G	G-F	G	G-F	F	P	G	F
London silt loam	G-F	F	G	G-F	G	F	G-F	F	VP	VP	G	F	G	G-F	G	G-F	F	P	G	F
Maplewood silt loam	F	P	G-F	F-P	G-F	P	F	VP	VP	VP	G-F	P	G-F	F	G-F	F	VP	VP	G-F	P
Muck																				
Parkhill loam	F	P	G-F	F-P	G-F	P	F	VP	VP	VP	G-F	P	G-F	F	G-F	F	VP	VP	G-F	P
Parkhill silt loam	F	P	G-F	F-P	G-F	P	F	VP	VP	VP	G-F	P	G-F	F	G-F	F	VP	VP	G-F	P
Perth clay loam	G-F	F	G	G-F	G	F	G-F	F	VP	VP	G-F	F	G	G-F	G	G-F	F	P	G-F	F
Perth silt loam	G-F	F	G	G-F	G	F	G-F	F	VP	VP	G	F	G	G-F	G	G-F	F	P	G	F
Tavistock silt loam	G-F	F	G	G-F	G	F	G-F	F	VP	VP	G	F	G	G-F	G	G-F	F	P	G	F
Wauseon sandy loam	P	VP	P	VP	P	VP	P	VP	VP	VP	P	VP	F	P	F	P	P	VP	F	VP

*These ratings are based on general farm management practices and apply specifically to Oxford County.

Counties generally, soil types are not. To overcome this problem, it was decided to interpolate the Norfolk County soil types into the Oxford rating system. On looking closely at the Oxford rating of tobacco soil types, a trend is found to be apparent. Within the soil series, soil types are ranked in the soil survey according to textural composition. The Fox series is the best illustration of the trend. The soil types are ranked as follows (from Table 1)::

Fox loamy sand	G-F
Fox sandy loam	G
Fox fine sand loam	G

Sandy loams are ranked one category higher than loamy sands. Also, in the Burford series (see Table 1), sandy loam is one category higher than loam. The soil types, therefore, appear to range from those with silt loam textures, to sandy loam textures, through loamy sand, sands and gravels. A tentative ranking of textural composition on this basis is shown in Table 2. The next step is to select the pertinent ranked soil series and their soil types from the Soil Survey and group them in preparation for the interpolation. These soil series selected from the Oxford rating are grouped in Table 3. All the soil types on which the 41 sample farms are located are taken and interpolated in the rating system in Table 4 on the basis of the textural composition. Watrin is the only soil series not rated in the Oxford rating, but Watrin soils are so-named because

TABLE 2*

A RANKING OF TEXTURAL COMPOSITIONS SUGGESTED BY THE OXFORD SOIL SURVEY RANK

Fine sandy loam
Medium sandy loam
Coarse sandy loam
Loamy sand
Gravelly sandy loam
Fine sand
Medium sand
Gravel

* Taken from the Oxford Soil Survey

TABLE 3*

SOIL SERIES AND SOIL TYPES WHICH OCCUR IN BOTH NORFOLK AND OXFORD COUNTIES

Fox fine sandy loam	(G)	1
Fox sandy loam	(G)	1
Fox loamy sand	(G-F)	2
Brady loamy sand	(VP)	6
Granby sand	(VP)	6

* Taken from the Oxford Soil Survey

TABLE 4

INTERPOLATION OF THE NORFOLK SOIL TYPES ON WHICH THE SAMPLE FARMS OCCUR INTO THE OXFORD SOIL SURVEY RATING SYSTEM

Fox fine sandy loam	1
Fox sandy loam	1
Fox loamy sand	2
*Fox gravelly sandy loam	3
*Fox coarse sand	3
*Plainfield sand	3
------------	4
*Watrin sand	5
*Brady sandy loam	5
Brady loamy sand	6
Granby sand	6

* Denotes interpolated Norfolk soil types

they contain water. Accordingly, they have a low rank. Plainfield sand is the soil type name used on the Norfolk County Soil Map, but it is now called Fox sand, rolling phase. Three soil types of the Fox series are rated 3: Fox gravelly sandy loam, Fox coarse sand, and Plainfield sand. Watrin, because of its water content is rated 5. Brady sandy loam is rated one category better than Brady loamy sand, just as Fox sandy loam is rated one category better than Fox loamy sand in the Oxford Soil Survey.

Another problem presented itself in that textural compositions recorded by Lane for the sample farm sites were not the same as those indicated by the soil type name on the Norfolk County Soil Map for the same site (see Table 5). This textural composition information recorded by Lane for each of the sites was ranked as it was compared with the soil type information provided by the Norfolk County Soil Map for the farm sites.Three fractional figures, .5 and .25, and .75 are assigned according to the difference between Lane's recorded textural information, and the textural information provided by the Norfolk County Soil Map. For example, if the site is on Fox sandy loam according to the soil map, and Fox sandy loam is rated 1, (see Table 4), and if Lane's textural information for the site indicates a texture of sandy loam, the rating is 1.0. But if Lane's information indicates the texture is fine sandy loam, this is considered to be better than sandy loam so the rating is .75. If Lane indicated loamy sand were on the site, the rating would be 1.25. The fraction, .25, .5, or

TABLE 5

COMPARISON OF TEXTURAL COMPOSITIONS INDICATED BY THE NORFOLK COUNTY SOIL MAP AND THOSE RECORDED BY LANE.

SAMPLE SOIL NUMBER	NORFOLK SOIL MAP SOIL TYPE	LANE'S TEXTURAL COMPOSITION RECORD
1	Fox coarse sand	coarse sandy loam
2	Fox coarse sand	sandy loam
3	Brady sandy loam	sandy loam
4	Fox sandy loam	sandy loam
5	Fox coarse sand	loamy sand
6	Watrin sand	sandy loam
7	Fox gravelly sandy loam	sandy loam
8	Fox gravelly sandy loam	sandy loam
9	Fox gravelly sandy loam	loamy sand, gravelly sandy loam
10	Watrin sand	loamy sand
11	Fox gravelly sandy loam	sandy loam, gravelly sandy loam
12	Fox gravelly sandy loam	sandy loam, gravelly sandy loam
13	Fox gravelly sandy loam	sandy loam, gravelly sandy loam
14	Fox gravelly sandy loam	medium sandy loam to gravelly loam
15	Fox gravelly sandy loam	sandy loam
16	Fox gravelly sandy loam	sandy loam
17	Granby sand	sandy loam
18	Watrin sand	sandy loam
19	Plainfield sand	medium sandy loam
20	Plainfield sand	sandy loam
21	Plainfield sand	sandy loam
22	Fox coarse sand	loamy sand
23	Plainfield sand	loamy sand, sandy loam
24	Plainfield sand	loamy sand
25	Fox fine sandy loam	loamy sand, sandy loam
26	Fox fine sandy loam	fine sandy loam
27	Plainfield sand	sandy loam
28	Plainfield sand	medium sandy loam
29	Watrin sand	loamy sand
30	Fox fine sandy loam	silt loam
31	Plainfield sand	fine sandy loam
32	Plainfield sand	sandy loam
33	Watrin sand	loamy sand
34	Plainfield sand	loamy sand
35	Plainfield sand	loamy sand
36	Fox coarse sand	sandy loam, gravelly sandy loam
37	Fox coarse sand	sandy loam
38	Brady sandy loam	heavy sandy loam
39	Fox coarse sand	sandy loam, loam over gravel
40	Fox sandy loam	loamy sand
41	Fox coarse sand	sandy loam

.75, is added or subtracted. The final rating, called Rank I, has the data recorded under the heading "Rank I" in Appendix 2. These data are tested by graph analysis, and linear regression analysis in Section II.

It is clear that too many of the interpolated soil types in Rank I fall into the rating 2.5 (see the data in Appendix 2) with the result that trends of association of these individual interpolated soil types with yield data are likely to be less discernable. To overcome this clustering of the soil types within the 2.5 rating, it was decided to take the interpolated soil types, which fall in either category 3 or 5 (Table 4) and rank them so they fall in four categories, 2, 3, 4, and 5. This was done in Table 6. This time the somewhat subjective fractional additions used in Rank I, .25, .50, and .75, were expanded to .1, .2, .3, .4, .5. These were intended to be directly associated with the ranking of Fox series soil types (see Table 7). This fractional ranking is expanded to .2, .4, .6, .8, 1.0, to make the ranking continuous. The soil type information, as provided by the Norfolk soil map, is also ranked again. The Fox series is placed in three ranked soil type categories, the sandy loams (1), the loamy sands (2), and the sands (3). The gravel in Fox gravelly sandy loam takes it out of category 1, and places it in category 2. Plainfield sand, now known as Fox sand rolling phase, was placed one category lower than the soil types ranked according to sand content, because of its rolling topography.

This new ranking of soil types is shown in Table 6.

In Rank II the fractional rank is derived in the same manner as that for Rank I. Lane's textural information, and the Norfolk soil map textural information are compared as in Table 7. If the Norfolk soil map indicates Fox coarse sand (.6) and Lane's information indicates fine sandy loam (.2), then the difference is -.4. This fraction is added to the Fox coarse sand rating (3) to give the fractional rank, 2.6. According to the rating system, fine sandy loam is better than coarse sand by .4. The data for this ranking, called Rank II, is shown in Appendix 2 for each of the 41 sample farms. In the analysis, the ranked soil texture information and the ranking of the Norfolk soil types are tested separately against yield and quality data to determine the value of their weighting before they are tested together as Rank II.

To this point, both the data from the 1928 Norfolk County Soil Map, and that textural information recorded by Lane were assumed to have been found by Lane, within an area designated a particular soil type by the Norfolk County Soil Map. There is an obvious anomaly here. Soil types are named on the basis of the soil texture characteristics found within a soil series. Thus either the Norfolk County Soil Map textural characteristics are incorrectly recorded, or Lane's textural information is incorrectly recorded. Evidence supporting the verity of Lane's data is derived from the comparison of the Oxford County Soil Map, and the Norfolk County Soil Map. The Oxford County

TABLE 6

NORFOLK COUNTY SOIL MAP DATA RATED FOR RANK II

Fox fine sandy loam	1
Fox sandy loam	1
Fox loamy sand	2
*Fox gravelly sandy loam	2
Fox coarse sand	3
*Plainfield sand	4
Watrin sand	5
Brady sandy loam	5
Brady loamy sand	6
Granby sand	6

*Denotes new catagories

TABLE 7

RANKING OF LANE'S TEXTURAL DATA ACCORDING TO THE RATING OF NORFOLK COUNTY SOIL TYPE DATA

NORFOLK SOIL TYPE RATED FOR RANK II		LANE'S TEXTURE RANK (x.2)	
Fox fine sandy loam	1	fine sandy loam	.2
Fox sandy loam	1	medium sandy loam	.2
	1	coarse sandy loam	.2
Fox loamy sand	2	loamy sand	.4
Fox gravelly sandy loam	2	gravelly sandy loam	.4
Fox coarse sand	3	coarse sand	.6
	4	silt loam	.8
	5	gravel	1.0

Soil Map is considerably more detailed. The Oxford County Soil Map was completed in 1961 so that it is assumed that more modern and accurate methods of assessing soil type were used. Consequently, it was decided to use the soil series data provided by the Norfolk County Soil Map, but to name the soil types on the basis of textural information provided by Lane.

With the renaming of the soil types, a number of new soil types unaccounted for by the Norfolk County Soil Map were found to occur. These are shown in Table 8, Rank III. It is interesting to note that no soil types containing sand compositions alone are found to exist (see Table 5). The "new" soil types are interpolated into the ranking of soil types on the basis of textural trends as before. Rank III is then tested in Section II. Rank III data are shown for each of the 41 farms in Appendix II.

THE DEPTH OF THE CULTIVATED LAYER AS A PREDICTIVE VARIABLE

In collecting data for his classification system, Lane expected to find evidence of erosion. This evidence was to have been included in the classification system as a weighted figure in assessing the productive capability of the site. Erosion figures were to have been recorded in Section C. of Form II under "Depth of Cultivated Soil" (see Appendix 1). Instead of finding evidence of erosion, it appeared that the depth of the cultivated layer was increasing. Tobacco farmers generally cultivate to six or seven inches; Lane found that

TABLE 8

RANK III

Fox fine sandy loam	1
Fox sandy loam	1
*Fox coarse sandy loam	1
Fox gravelly sandy loam	2
Fox loamy sand	2
*Fox silt loam	2
Fox coarse sand	3
*Plainfield sandy loam	3
*Plainfield loamy sand	4
Plainfield sand	4
*Watrin sandy loam	4
*Watrin loamy sand	5
Watrin sand	5
Brady sandy loam	5
Brady loamy sand	6
*Granby sandy loam	6
Granby sand	6

* Denotes "new" soil types.
Note, no soil types containing pure sand textures are now found.

average depths of this layer for each of the sample farms ranged from 7 to 14 inches. Lane took at least three sample measures from each site. Inputs, it appeared, were being added to the soil during or after cultivation (see Figure 3).

Three possible sources for this material which was causing the increase were suggested: soil slump or redeposition from high areas to low areas, wind deposition, and inputs resulting from cultivation practices. If soil creep were occurring,at least one area of the farm site, the high area, would have a continuous depth of cultivated layer measure of 7 inches or less. If slump were the case he should have always found a minimum measure of 6 or 7 inches, but his minimum measures ranged from 7 to 12 inches (see Table 9). With wind erosion two things would occur; a large area would show signs of erosion, and a large area, the area of the thickest cultivated layers, would have fine textural compositions, textures suitable for wind transportation. First, Table 7 shows a ranking of texture. This ranking to some extent indicates the ease which the material could be wind transported. For example, fine sandy loam could be transported more easily than coarse sand or gravel. Fine sandy loam is designated .2, and coarse sand and gravel are .6 and 1.0. Silt loam occurs in the wrong place in this index of wind transportability, but silt loam only occurs on one sample site. Comparing data in Appendix 2, where the deepest average depths of the cultivated layers occur, the fine material, indicated by .2,

FIG.3 ILLUSTRATION OF THE INCREASING DEPTH OF CULTIVATED LAYER

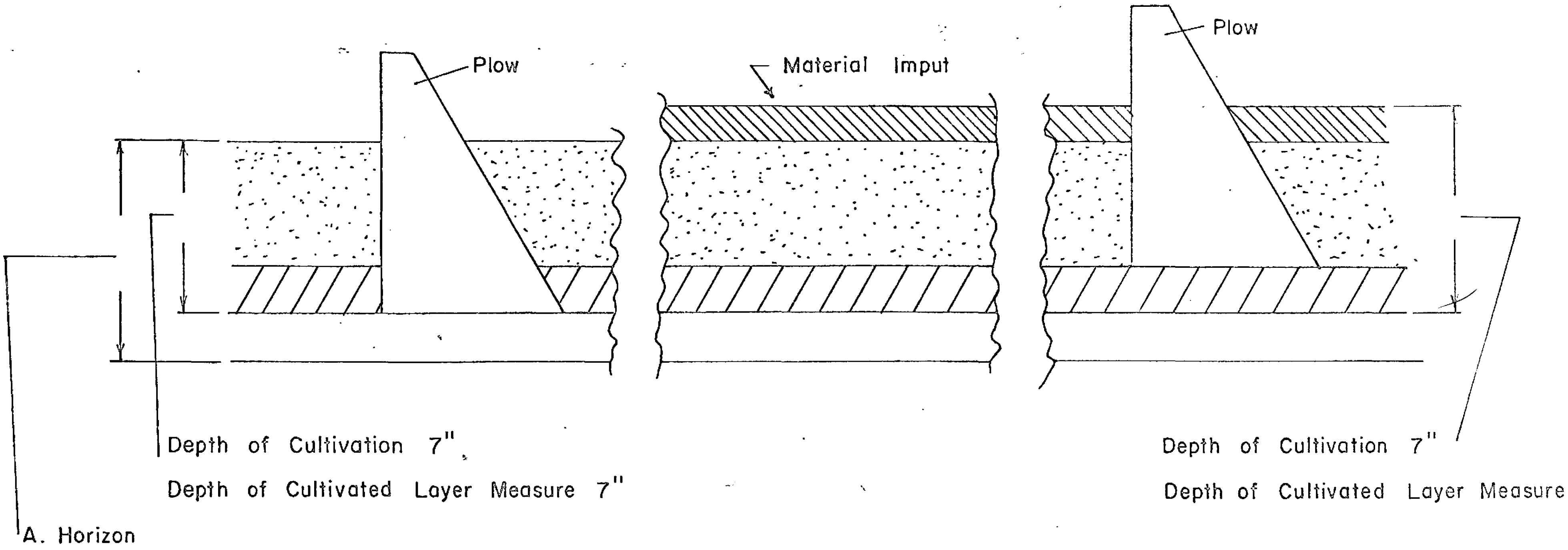


TABLE 9

DEPTHS OF THE CULTIVATED LAYER PROVIDED BY LANE

SAMPLE NUMBER	RANGE OF SAMPLE IN INCHES	AVERAGE MEASURE IN INCHES
1	8 - 10	9.0
2	9 - 11	10.
3	no data	9.4**
4	9 - 12	10.5
5	8 - 12	10.0
6	9 - 14	11.5
7	9 - 12	10.5
8	no data	9.4**
9	8 - 11	9.5
10	8 - 12	10.0
11	8 - 12	10.0
12	10 - 12	11.0
13	8 - 10	9.0
14	8 - 10	9.0
15	6 - 9	7.5
16	8 - 10	9.0
17	6 - 8	7.0
18	no data	9.4**
19	6 - 8	7.0
20	7 - 11	9.0
21	6 - 8*	7.0
22	8 - 10*	9.0
23	6 - 10	8.0
24	6 - 8	7.0
25	6 - 12	9.0
26	12 - 16	14.0
27	6 - 10	8.0
28	7 - 9	8.0
29	8 - 12	10.0
30	10 - 12	11.0
31	10 - 12	11.0
32	10 - 12	11.0
33	10 - 12	11.0
34	6 - 10	8.0
35	8 - 10	9.0
36	8 - 12	10.0
37	8 - 10	9.0
38	8 - 10	9.0
39	8 - 10	9.0
40	11 - 13	12.0
41	no data	9.4**

*This field had only been cleared from timber for six years. Its rotation field ranged from 12-13 inches.

**Where no data were available, the average figure 9.4 is used.

does not necessarily occur. Secondly, isopleth maps of ranked textural data (Figure 4) and average depths of the cultivated layer (Figure 5) show little visual correlation. Finally, the textural data from Table 7 are correlated with depth of cultivated layer data.

Because of the extreme variations in the depth of the cultivated layer, and evidence suggesting that it was increasing due to cultivation practices since farmers may put up to 1,400 pounds of fertilizer per acre per season on their farms,[2] it was tested to determine its predictive capability in terms of yield and quality.

YIELD AND QUALITY DATA

Yield data are provided by Lane in the form of the average number of pounds per acre of tobacco each of the tobacco farms yielded for the 1960 and 1962 growing seasons. Yield data were unavailable for sample farms 18 and 21 for 1960. Taken as representative of the quality of tobacco for each of the 41 samples, is the average price per pound of tobacco for each farmer received at the end of the 1962 growing season. There are some problems with taking these data as representative of quality, for curing difficulties can lower the market quality of the tobacco. Also since tobacco is sold at auction, and although minimum prices are set for different quality categories of tobacco, there may be a considerable range of prices

---

[2] J. M. Elliot, Ontario Flue-cured Tobacco Soils, Guelph, p 12.

FIG.4 ISOPLETH MAP ILLUSTRATING THE DISTRIBUTION OF SOIL TEXTURES

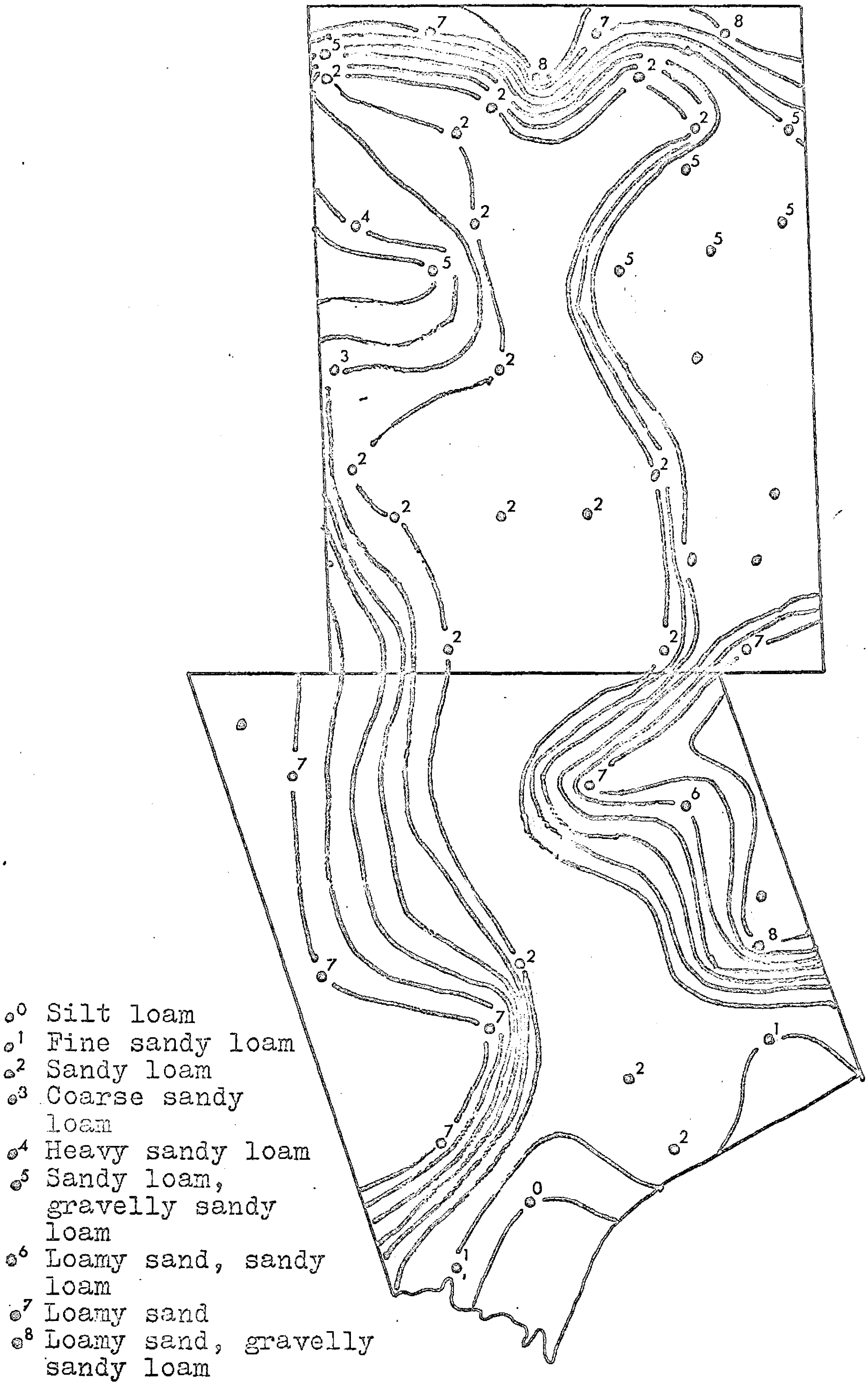
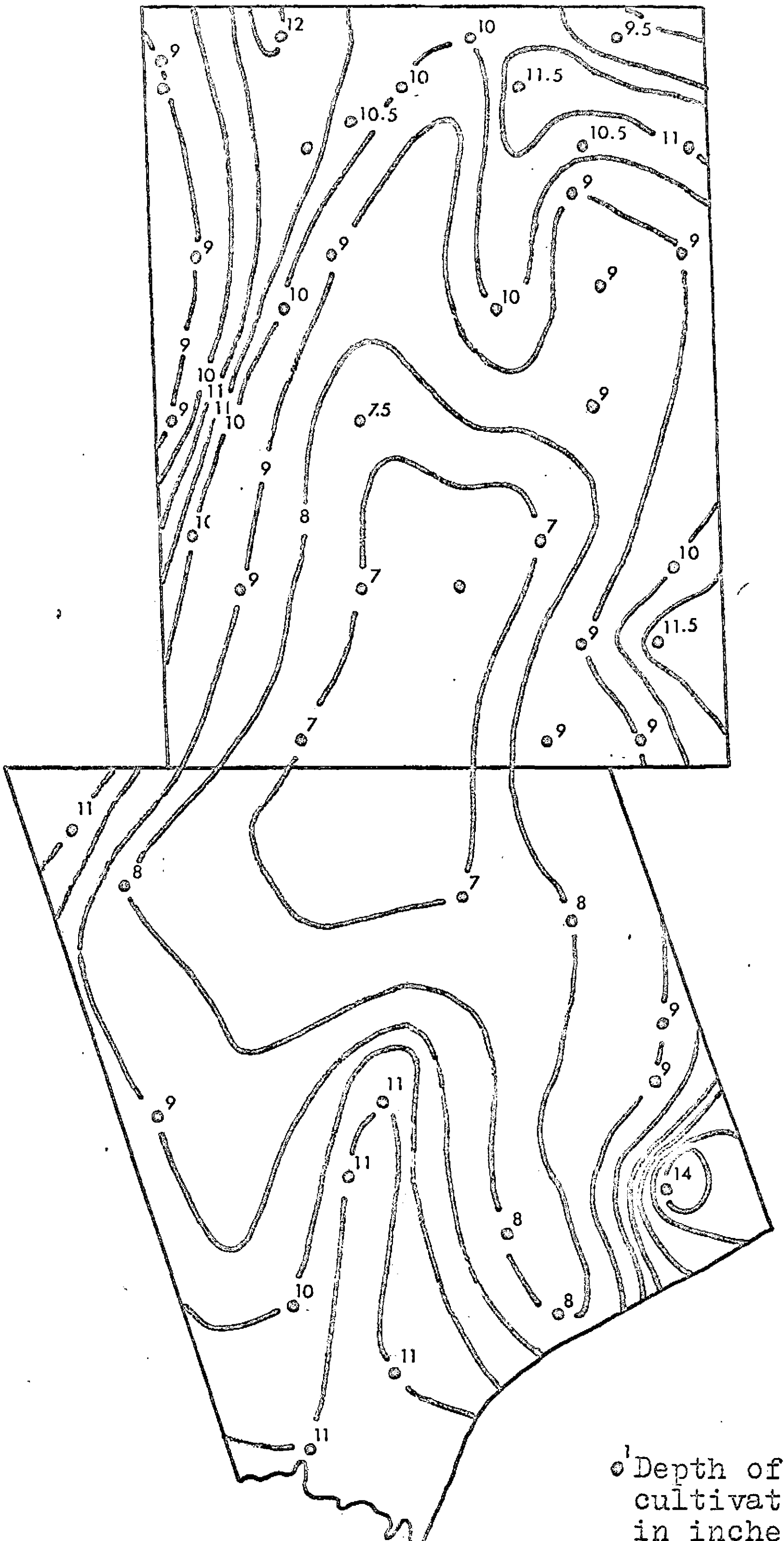


FIG.5 ISOPLETH MAP ILLUSTRATING THE DISTRIBUTION OF THE DEPTHS OF THE CULTIVATED LAYER



●Depth of the cultivated layer in inches received by two different farmers for the same quality tobacco. Prices received depend very much on the demand of the buyers. These data, 1960 yield, 1962 yield, and 1962 quality (see Appendix 2) are used as dependent variables in the analysis of the classification systems.

CHAPTER II

THE TESTS

METHODS OF ANALYSIS

Three methods of analyzing of the data are used; graphic analysis, simple regression, and multiple regression. Regression analysis enables the investigation of trends in the relationships of two or more sets of data by measuring the nature of the function linking X and Y, $Y = f(X)$, where Y is considered to be an 'effect', X a 'cause', and f is the symbolic statement of 'function of'. To determine the function, the best-fit regression line (the line which best fits the series of points if plotted on a graph) is found mathematically. This line is of the general form $Y = a + bX$.

When an effect is not explicable in terms of one cause but in terms of a group of causes, there is an expression in which an effect (Y) can be associated with a number of causes in combination $(X_1 X_2 \ldots X_n)$. This method of analysis is called multiple-regression analysis, where in mathematical terms, Y is given by:

$$Y = a + bX + cX_2 \ldots + zX_n.$$

When certain variables are found to be significant as they associate with dependent variables, it is useful to plot these data on graphs to get a more detailed impression of their association. These methods of analysis are carried out in this chapter in three stages: the simple linear regression analysis is considered first for all the data, then the multiple linear regression analysis, and finally, selected variables are plotted on graphs.

SIMPLE LINEAR REGRESSION ANALYSIS

In analysis of data pertaining to agricultural geography, correlations are expected to be low because of the complex variables that must be dealt with. Accordingly, significant correlations are those of at least +/-.32.

The data for Lane's classification system (listed in Appendix 2) are compared with yield and quality data (also listed in Appendix 2). The results are shown in Table 10. There are two methods of deriving the data for testing Lane's classification system. The second method is used as a check on the first. These two sets of data correlate, with r = .97. This indicated it is possible to proceed with the test utilizing these data.

No significant correlation takes place between Lane's classification system and 1962 yield data (r = -.15). Significant correlation takes place between Lane's classification system and 1960 yield data and 1962 quality data where the association with the 1960 yield data has r = -.53, and the association with the 1962 quality data has r = -.52. The drainage data, which are comprised in the classi-

TABLE 10

CORRELATION MATRIX*

CLASSIFICATION	Drainage	Topography	Classification	(Check)	Rank I	Soils	Textural Ranked	Rank II	Rank III	D. Cult. Layer	Yield 62	Yield 60	Quality 62
Texture	-.06	-.10	-.02	.01	.01	-.10	.49	-.08	-.11	-.04	.08	.06	.11
Drainage		-.36	.99	.96	.73	.66	-.15	.69	.65	-.02	-.16	-.52	-.52
Topography			-.30	.23	-.29	-.41	.40	-.35	-.13	.10	.09	-.05	.11
Classification				.97	.73	.65	-.10	.68	.65	-.01	-.15	-.53	-.52
(Class. Check)					-.72					-.02	.09		
RANK I													
Rank I										-.14	-.35		
RANK II													
Norfolk soils							-.19	.98	.83	-.35	-.38	-.51	-.43
Ranked texture								-.08	.10	.10	.02	-.13	.18
Rank II									.89	-.32	-.38	-.54	-.43
RANK III													
Rank III										-.23	-.39	-.59	-.46
D. of cultivated Layer											.34	.12	.17

*Data in Appendix 2

fication system, also have a significant correlation with r = -.52 as it compares with 1960 yield and 1962 quality data. The other data within the classification system for topography and texture have little significant relation to the dependent variables.

The first ranking of Norfolk County soil type data, called Rank I, is correlated with 1962 yield data. Here r = -.35. At this stage in the investigation no correlation was made with 1960 yield and 1962 quality data.

Rank II is comprised of ranked Norfolk County soil type data taken from the Norfolk County Soil Map, and ranked textural information provided by Lane. The ranked data from the Norfolk soil map and Lane's ranked textural data were correlated seperately against yield and quality data to test the success of the ranking. The ranked textural data are compared with Lane's mathematically weighted textural data and found to correlate at r = .49. In association with yield and quality data, the ranked textural data are only slightly better correlated than Lane's mathematical weighting. Neither are significantly correlated with this data. The correlations of the ranking of the Norfolk County Soil Map soil type data with yield and quality, and Rank II with yield and quality data are essentially the same. Both are significantly correlated with r = -.38 for 1962 yield, and r = -.43 for 1962 quality. In the correlation with 1960 yield the soil type data correlated at r = -.51, and the aggregate Rank II (which comprised the additional weighted texture data) correlated at r = -.54. The addition of the textural data only brings a slight improvement in the correlation.

Rank III makes a new assessment of the soil types to be found in Norfolk County based on the textural information provided by Lane. These assessed soil types are ranked in the same way that the Norfolk County Soil Map soil types were in the preparation of Rank II. A correlation of $r = .65$ is indicated between Rank III and Lane's classification system, a relatively low correlation considering the two classification systems are dealing with the same material. However this figure does suggest some intercorrelation. Rank III correlates significantly with 1962 yield data, $r = -.39$, with 1960 yield data, $r = -.59$, and with quality data, $r = -.46$. In every case Rank III, which is a ranking of assessed soil types, is better correlated with yield and quality data than the ranked Norfolk County Soil Map soil type information.

The depth of the cultivated layer as an independent variable correlates significantly only with 1962 yield data, $r = .34$. It does not correlate significantly with Lane's ranked textural information. This tends to indicate that this material is not wind deposited.

LINEAR MULTIPLE REGRESSION ANALYSIS

All of the data are included in the linear multiple regression analysis in order to see whether or not individual factors within the classification systems (both Lane's and the Rank I, II, and III systems) may be more important as predictive variables than the classification systems themselves. In no cases are these factors selected over the classification systems themselves as being significantly associated with yield and quality. This suggests that all the factors have some value within the classification systems.

In the multiple regression analyses, all the independent variables are examined in combinations to determine which combinations are best predictive of yield or quality. Criteria are established so that only significant combinations are chosen. This process proceeds as follows. The partial F criteria for each variable X_1 and X_2 is evaluated and compared with a pre-selected percentage point of the appropriate F distribution. This provides a judgement on the contribution made by each variable as though it had been the most recent variable entered. If either variable provides a non significant contribution it is removed from the model. This process continues until no more variables will be admitted to the equation and no more are rejected. The F levels are selected according to the sample size. For this test, F_1 is 1.87, the significant level required to enter a variable into the regression equation, and F_2 is 1.7, the significant level required to remove a variable from the regression equation.

All of the data are first correlated against 1962 yield data. Rank III and the depth of the cultivated layer variables were selected as being significantly associated with the 1962 yield data, with $r = .47$. In the analysis with 1960 yield data, Rank III and Lane's classification system are selected as significant variables, with $r = .62$.

TABLE 11

REGRESSION EQUATIONS, CORRELATION COEFFICIENTS, AND STANDARD ERRORS OF ESTIMATE FOR 1960 YIELD, 1960 YIELD, AND 1962 QUALITY OF TOBACCO

DEPENDENT VARIABLES	REGRESSION EQUATION	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT (r)
1962 Yield	$Y = 123.18-86.27X_1 +67.81X_2$	34.01	0.47
1960 Yield	$Y = 194.50-75.23X_1 - 44.08X_3$	21.09	0.62
1962 Quality	$Y = 535.63-15.04X_3$	38.27	0.53

X_1 = Rank III
X_2 = Depth of the Cultivated Layer
X_3 = Lane's Classification

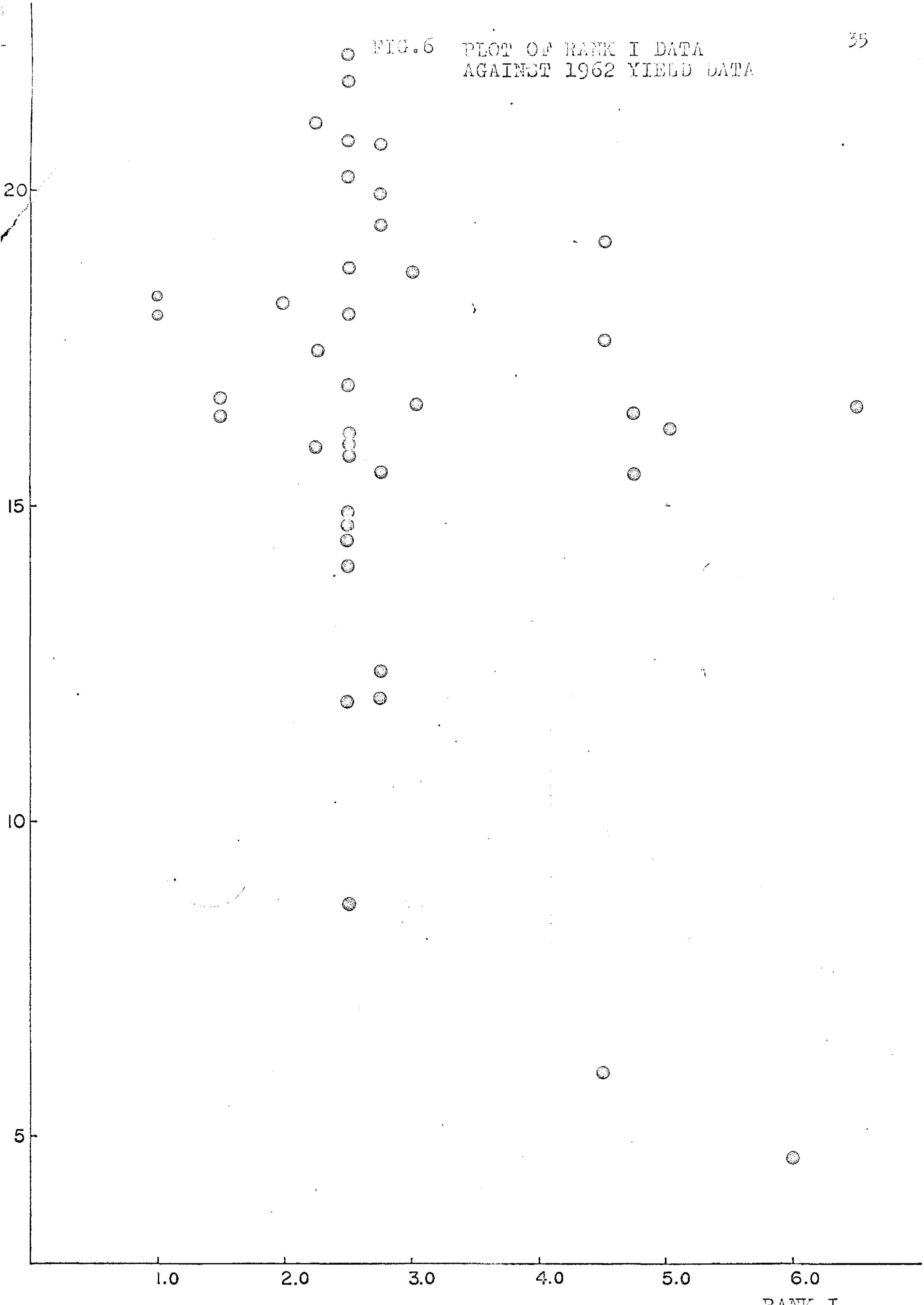
This figure may be considered somewhat high since there is some intercorrelation between Rank III and Lane's classification system as indicated in the simple regression analysis. Finally the data are analyzed with 1962 quality data. This time, only Lane's classification system is selected as being predictive of quality, r = .52. Again there is the problem of intercorrelation. It is clear, that the factors comprising the soil types, ranked in Rank III, which are associated with the quality of tobacco, are largely the same as those factors which are comprised in Lane's classification system. (For the multiple regression equations, see Table 11).

THE GRAPHS

In this study, graphs fulfill two purposes; first, they are used to give a more detailed picture of the association of two variables, and secondly, they are used to help illustrate the effect of a suspected additional variable. In the linear simple and multiple regression analysis, it is shown that in 1962 the depth of the cultivated layer is an important predictive variable, but in 1960 it is not. In 1960, Lane's classification system proved to be an important predictive variable. This suggested that an additional unaccounted-for seasonal variable is at work. To illustrate this situation, graphs were plotted for 1960 and 1962 seasons and compared.

The first graph plotted was to illustrate the relationship between Rank I and 1962 yield data. This graph is shown in Figure 6.

FIG.6 PLOT OF RANK I DATA AGAINST 1962 YIELD DATA



It is clear that there is a clustering of the plot in the area of rank 2.5. The result is that on the graph it is difficult to discern a trend of association between particular soil types and yield. The reason for this can be seen with reference to Table 4. The interpolated soil types are ranked 3 or 5. The addition of the fraction representing Lane's textural information puts soil types in rank 3 in either rank 2.25, 2.5 or 2.75, and too many fall in class 2.5. A ranking was carried out again to distribute the soil types which fall in rank 3 among categories 2, 3, and 4. Thus, whereas the addition of Lane's textural data as a fraction in Rank I created only three ranks for the interpolated soil type data, 2.25, 2.5 and 2.75, the ranking of the interpolated soil types in Rank II with the addition of the fraction became much more complex. This results in the spread of the data on the plot (see Figure 7), and the overall success of the ranking becomes discernable. That is, the interpolated data can generally be seen as forming a linear trend of association with yield, or a non-linear association. This trend is not illustrated by the interpolated data in the plot of Rank I.

On the basis of the plot of Rank I, it was felt that another device would be useful in discerning trends of association on the graphs. Future graphs are plotted using symbols instead of dots so that as far as possible, individual soil types could be recognized on the graphs. A computer program was worked out with the aid of D.R. Ingram, a graduate student in the McMaster Geography Department, which plots these graphs with symbols. The symbol key is shown in Table 12. Two keys are required since two different assessments of soil types located in Norfolk County are made by the Norfolk County Soils Map of 1928, and the assessment made in this paper in Rank III.

The Rank II data are plotted against 1962 yield data and 1960 yield data in Figures 7 and 8. The success of the new ranking in the expression of linear or non-linear trends of association is apparent. Comparing the distributions in Figures 7 and 8, it can be seen that distribution of the plot for the year 1962 is considerably more extended than that for the year 1960. It can also be seen that the ranking of the data seems to correlate with yields for all soil types except that designated "A". This soil type is Fox fine sandy loam and is rated "good" by the Oxford Soil Survey (see Table 1). According to both graphs it appears that it should be rated as low as Plainfield loamy sand.

Rank III data are plotted against 1962 and 1960 yield data (Figure 9 and 10). Again the same distension of the 1962 distribution as compared with the 1960 distribution of the plot is noted. Also, Fox fine sandy loam which retains the designation "A" still appears to be too highly ranked. Those soil types designated "D" and "E", Fox loamy sand and Fox silt loam, appear to be ranked too high, particularly Fox silt loam.

TABLE 12

GRAPH SYMBOL KEY

NORFOLK SOIL MAP DATA*

A- Fox fine sandy loam

B- Fox sandy loam

D- Fox gravelly sandy loam

E- Fox coarse sand

P- Plainfield sand

W- Watrin sand

X- Brady sandy loam

Z- Granby sand
* 1928 symbols

RANK III SOIL TYPE DATA*

A- Fox fine sandy loam and sandy loam

B- Fox coarse sandy loam

C- Fox gravelly sandy loam

D- Fox loamy sand

E- Fox silt loam

Y- Plainfield sandy loam

P- Plainfield loamy sand

W- Watrin sandy loam

X- Brady sandy loam and loamy sand

Z- Granby sandy loam
* 1962 symbols

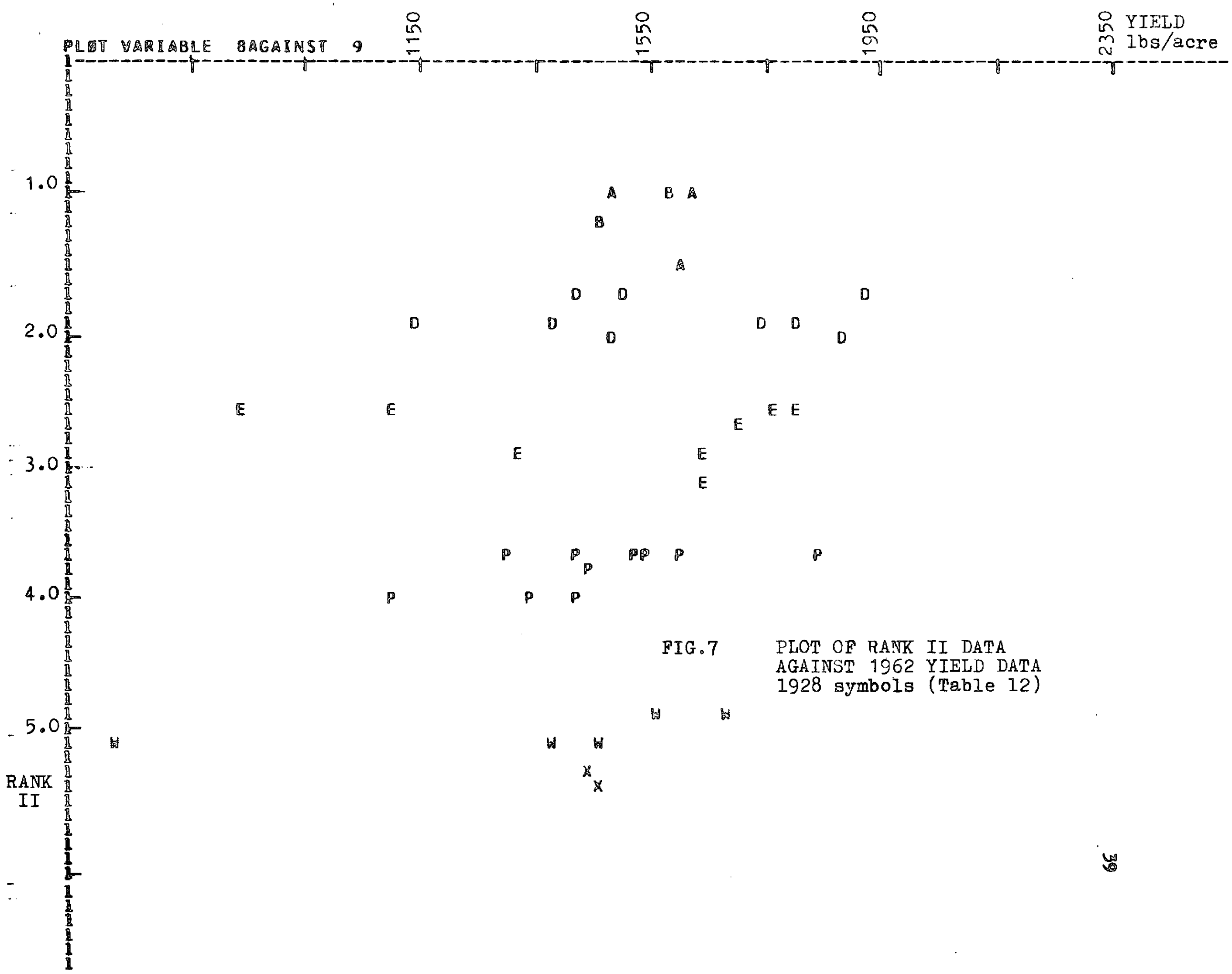


FIG.7 PLOT OF RANK II DATA AGAINST 1962 YIELD DATA 1928 symbols (Table 12)

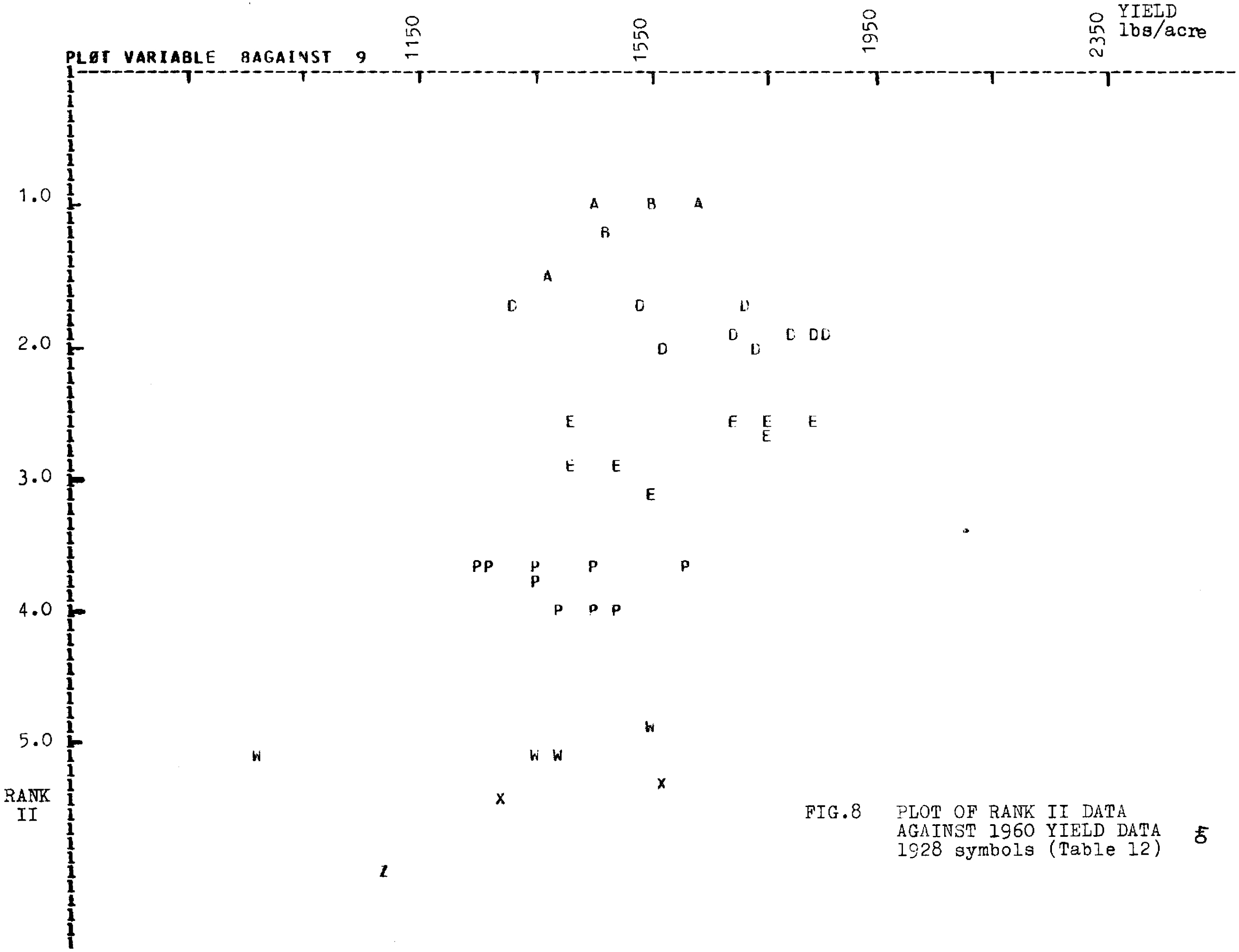


FIG.8 PLOT OF RANK II DATA AGAINST 1960 YIELD DATA 1928 symbols (Table 12)

5

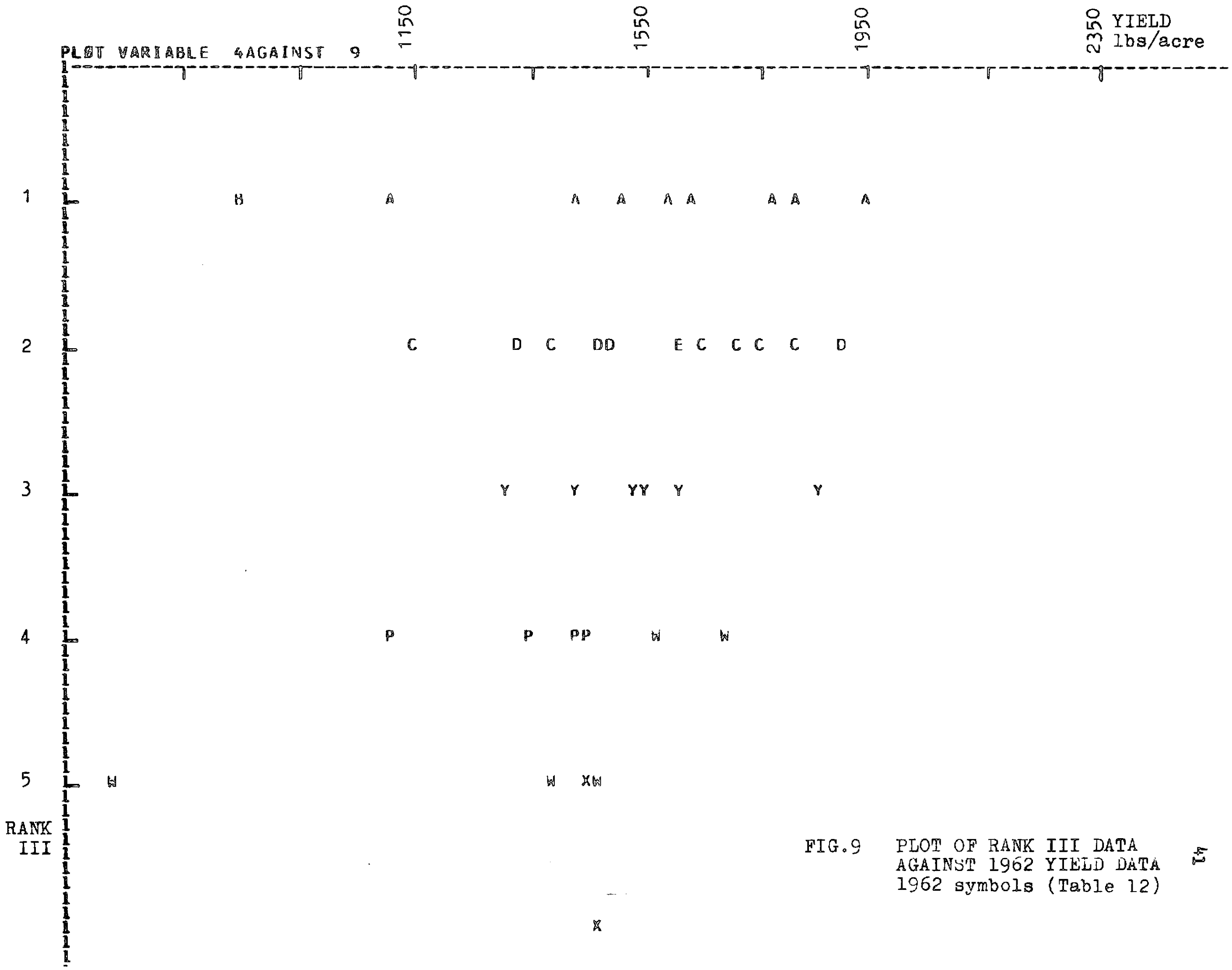


FIG.9 PLOT OF RANK III DATA AGAINST 1962 YIELD DATA
1962 symbols (Table 12)

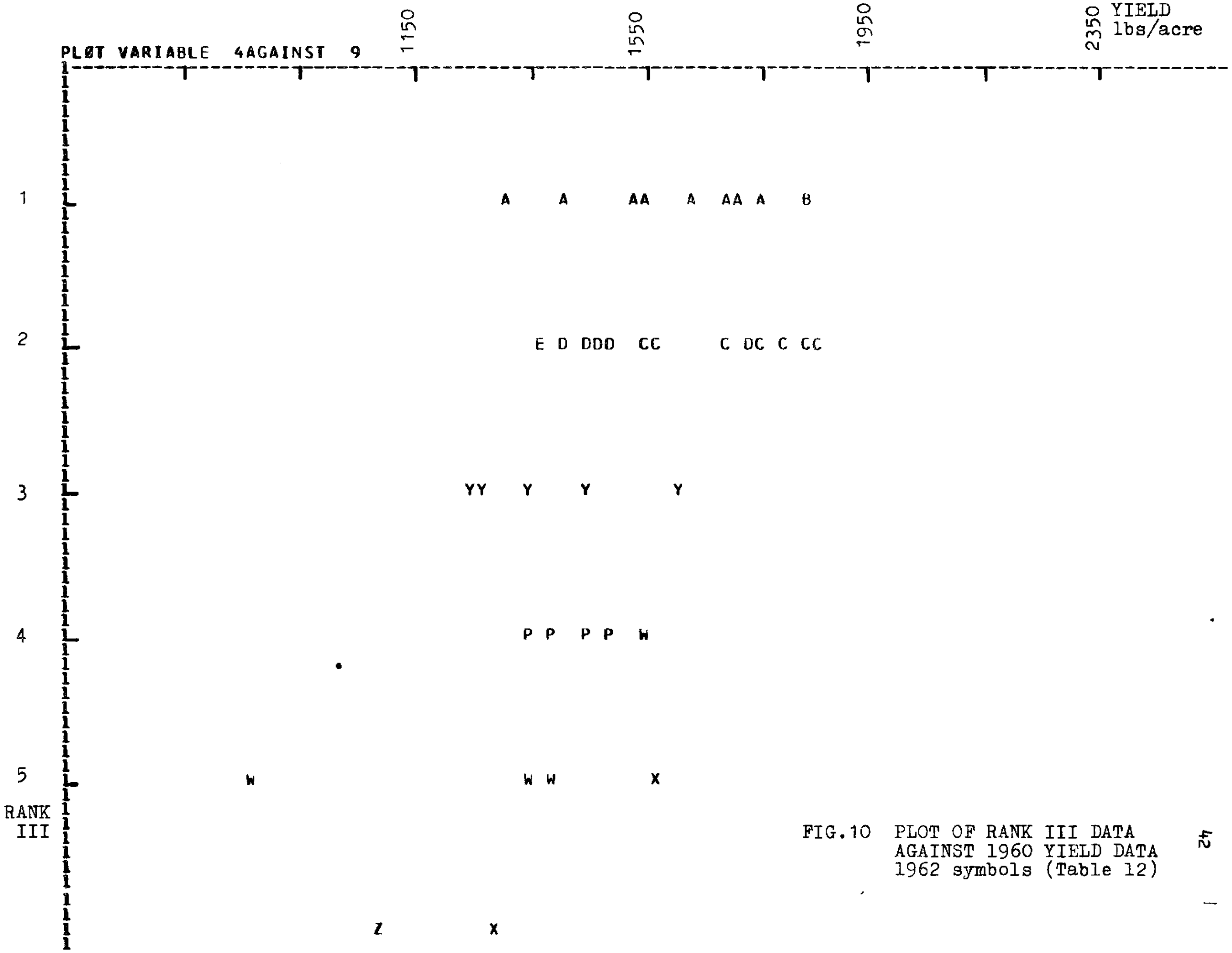


FIG.10 PLOT OF RANK III DATA AGAINST 1960 YIELD DATA 1962 symbols (Table 12)

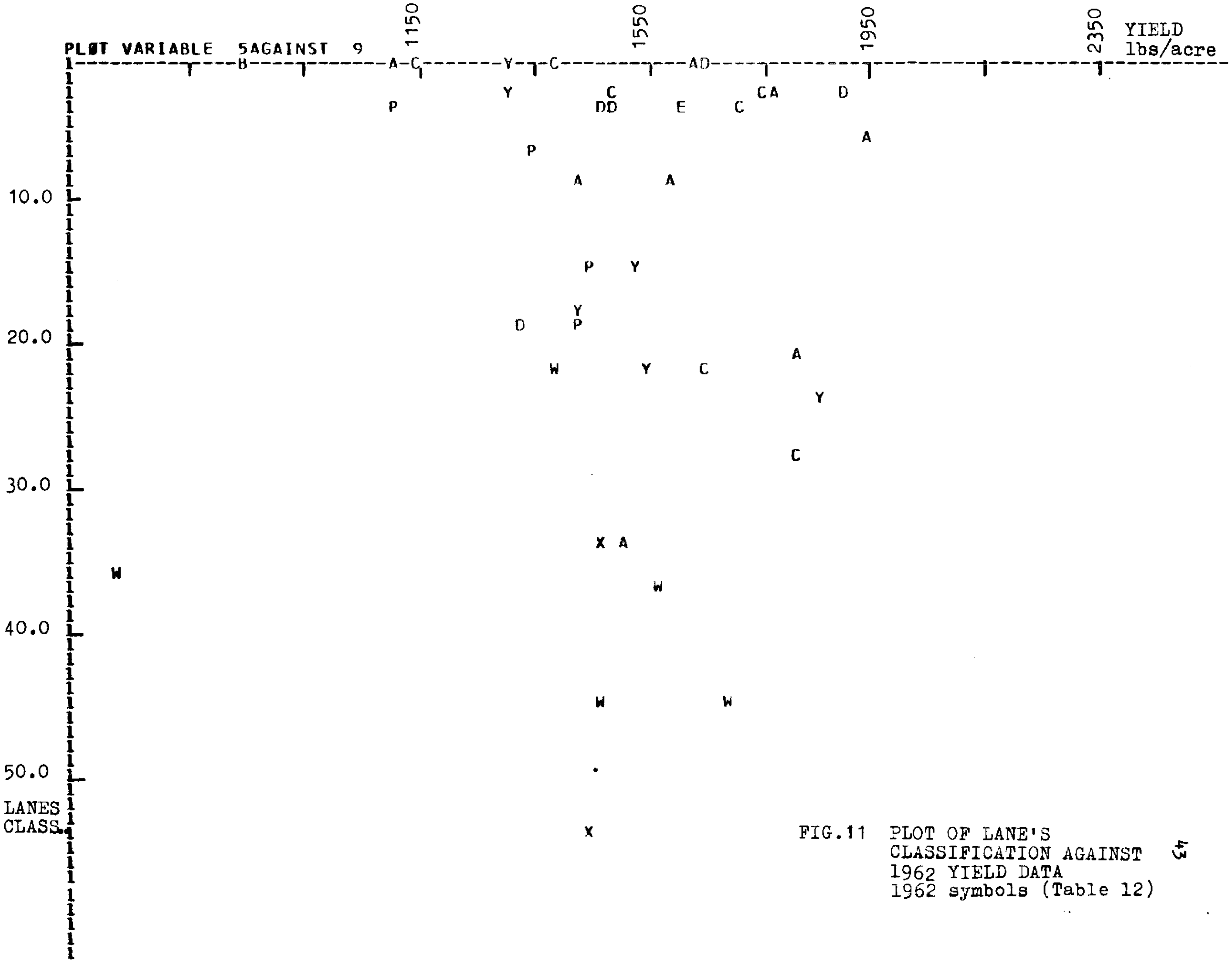


FIG.11 PLOT OF LANE'S CLASSIFICATION AGAINST 1962 YIELD DATA
1962 symbols (Table 12)

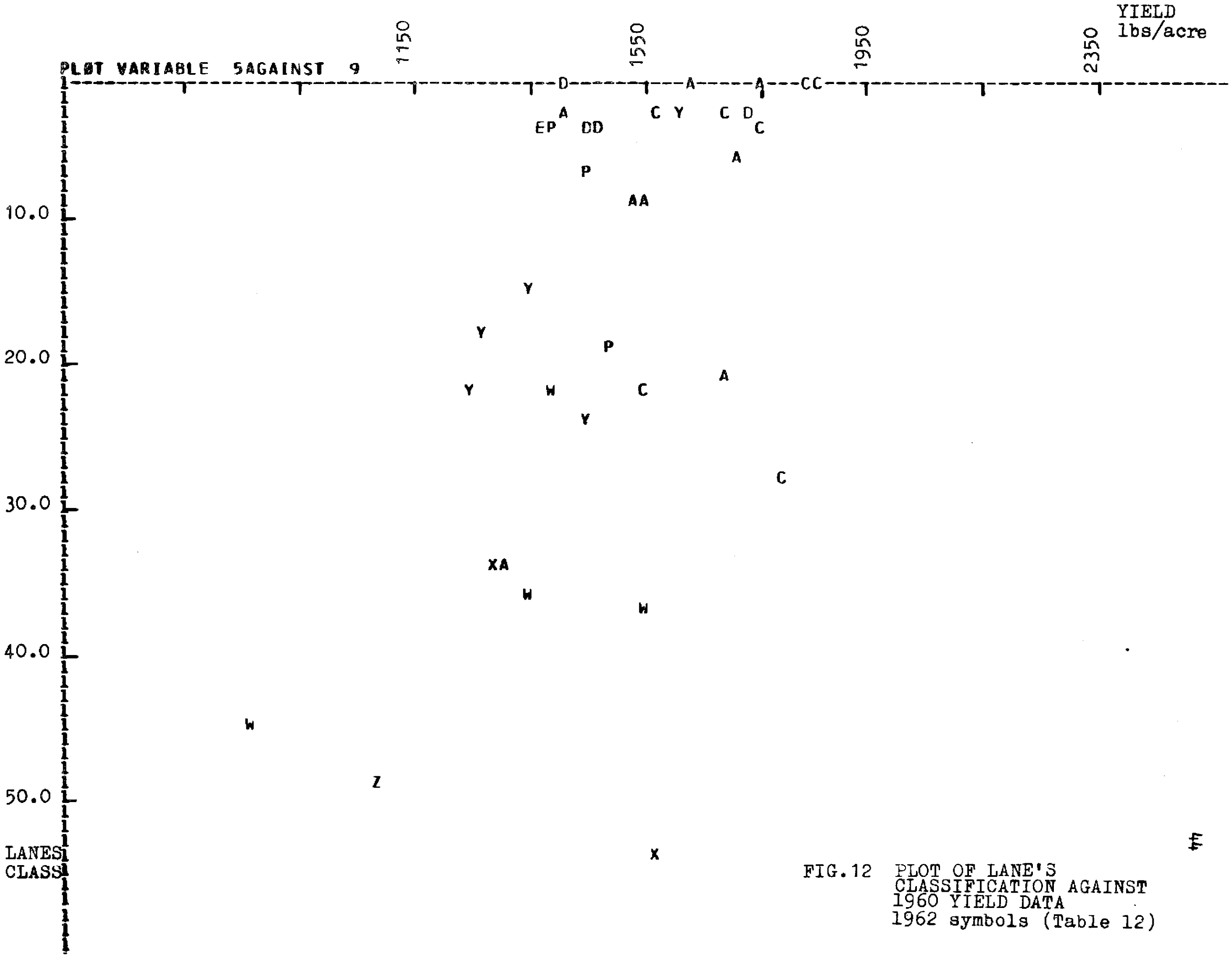


FIG.12 PLOT OF LANE'S CLASSIFICATION AGAINST 1960 YIELD DATA 1962 symbols (Table 12)

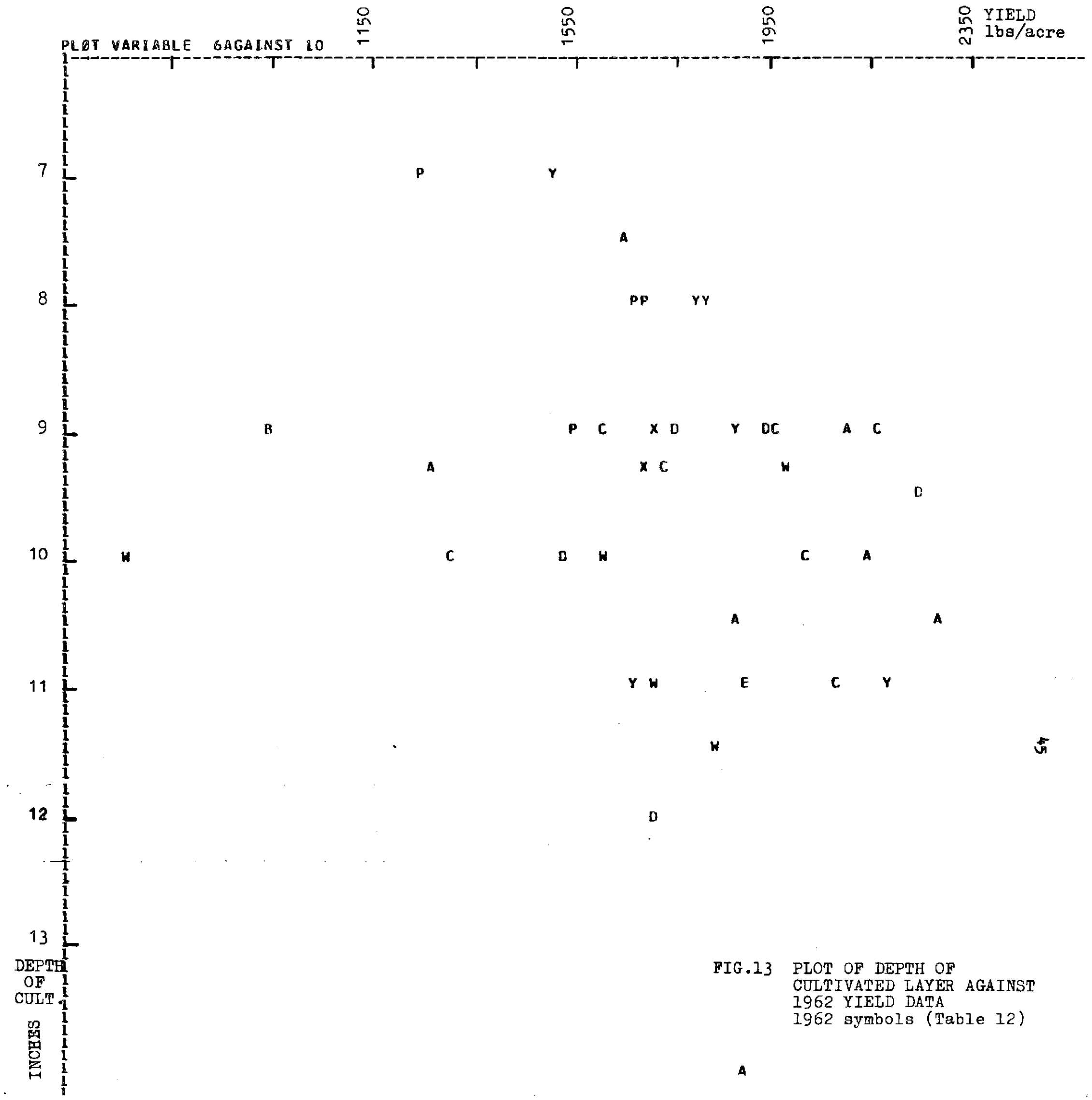


FIG.13 PLOT OF DEPTH OF CULTIVATED LAYER AGAINST 1962 YIELD DATA 1962 symbols (Table 12)

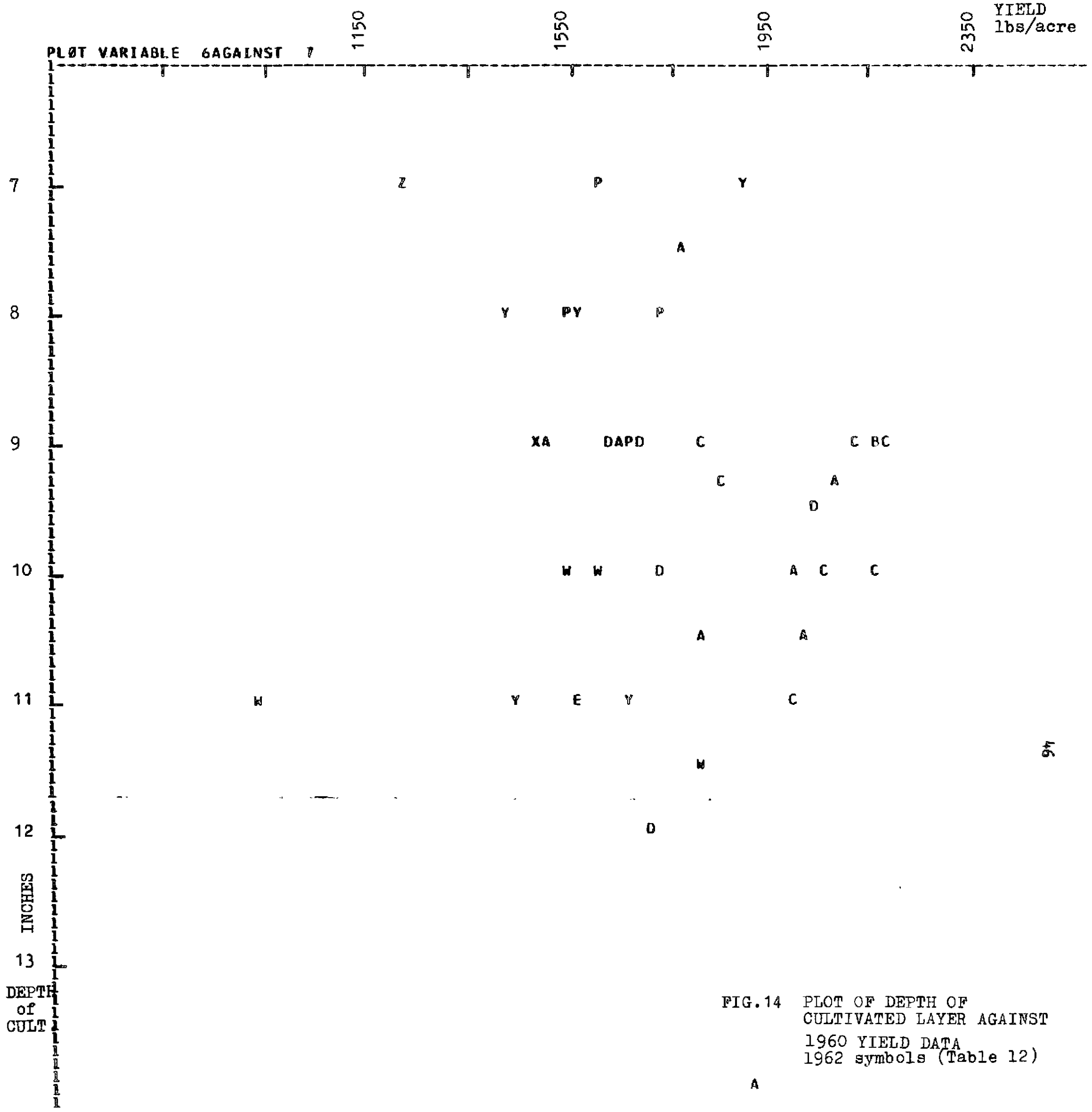


FIG.14 PLOT OF DEPTH OF CULTIVATED LAYER AGAINST 1960 YIELD DATA
1962 symbols (Table 12)

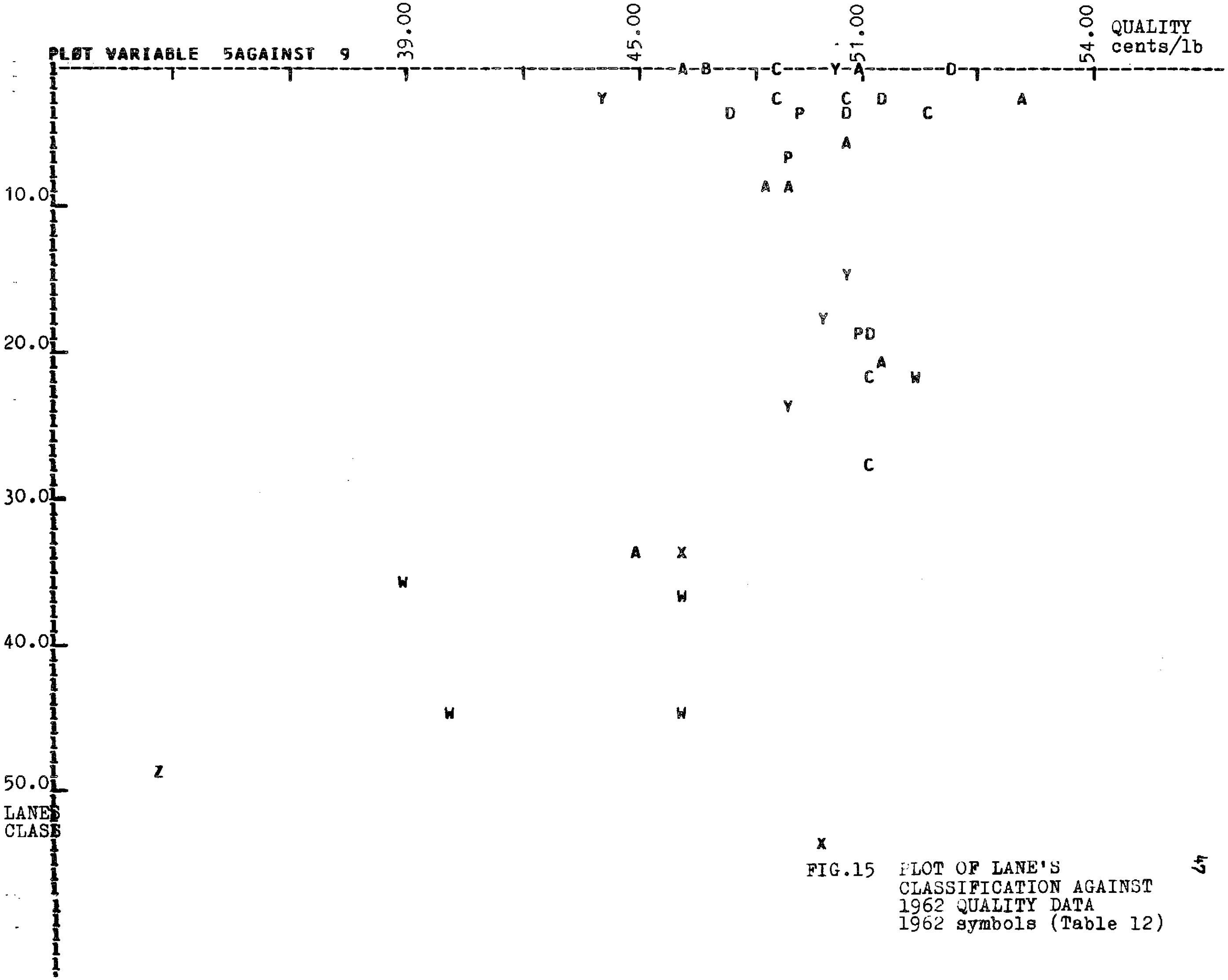


FIG.15 PLOT OF LANE'S CLASSIFICATION AGAINST 1962 QUALITY DATA 1962 symbols (Table 12)

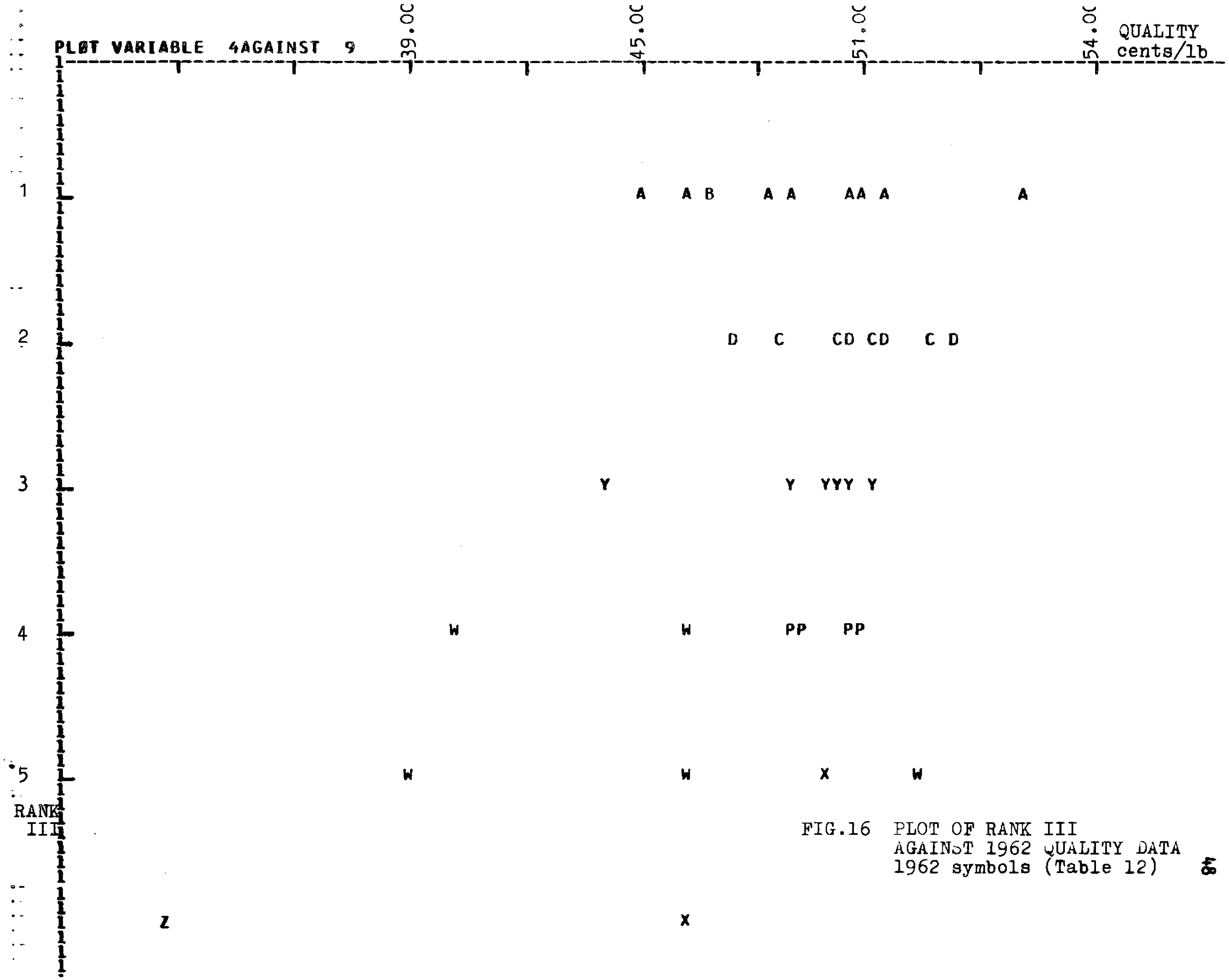


FIG.16 PLOT OF RANK III
AGAINST 1962 QUALITY DATA
1962 symbols (Table 12)

Lane's classification system data are plotted against 1962 and 1960 yield data (Figure 11 and 12). The trend of the distension of the distribution of the plot continues for the 1962 season. Fox fine sandy loam and silt loam remain poorly associated with increasing yields. As might be expected from the correlations, the trend of the distension of the distribution is reversed for the plot of the depth of the cultivated layer against 1962 and 1960 yield data, with the 1960 plot having poorer linear distribution (Figure 13 and 14). The depth of cultivated layer is significantly correlated with 1962 data and not significantly associated with 1960 yield data.

The only two variables which are significantly correlated with quality, Rank III, and Lane's classification system, are graphed in Figures 15 and 16. There is a marked visual similarity between the two distributions. This is also suggestive of the intercorrelation that appears evident in the regression analysis between Rank III and Lane's classification. Even the soil types, though derived differently, appear to have the same locations in the distribution. This again suggests intercorrelation.

SUMMARY OF ANALYSES

The two hypotheses are tested, that Lane's classification system is predictive of yield and quality, and that other selected physical factors are more predictive of yield and quality. The results show that Lane's classification system is predictive of yields in 1960, but not in 1962. It is predictive of 1962 quality. The ranking of soil types, known as Rank III, is predictive of 1962 and 1960 yields, and 1962 quality. The depth of the cultivated layer, under certain seasonal conditions, is predictive of yield.

The linear multiple regression analysis shows that Rank III and the depth of the cultivated layer combined are predictive of 1962 yields, while Rank III and Lane's classification system are best predictive of 1960 yields. Only Lane's classification system is selected as being best predictive of 1962 quality, although Rank III shows a high correlation with quality. This is due to the problem of intercorrelation between the independent variables.

In the course of the analysis, the mathematical weighting of the factors which make up the existing classification system were tested. These tests show that the weightings for topography and texture in the classification system have little significance. Lane's classification system is clearly reliant on the assessment of soil drainage. In the test, the textural data were weighted differently through a ranking of the data. These data were employed in the formulation of Rank II. This ranking of textural data, as a method of weighting, proved slightly better in its correlation with yield and quality than Lane's method of mathematical weighting, but it still remained insignificant in its correlation with yield and quality. Rank II is clearly based primarily on the ranking of Norfolk County Soil Map data. The Norfolk County Soil Map data considered to be incorrectly representative of present day soil types, and so a new assessment of soil types was made. This new assessment was employed in the formulation of Rank III. A slightly better correlation was obtained between Rank III and yield data than for the ranking of the Norfolk County Soil Map soil type data.

The graphs clearly illustrate a similarity in seasonal variation which affects the function of the selected physical factors in predicting yields. This suggests an unaccounted-for seasonal variable, or combination of variables, which act on the selected physical factors to make them more or less predictive of yields from season to season. The graphs also show that certain soil types may be incorrectly ranked.

CHAPTER III

CONCLUSIONS AND OBSERVATIONS

SUMMARY

Relationships between aspects of the physical environment and tobacco yield and quality have been examined by regression analysis. With the knowledge that a tobacco soil classification system was available, the hypothesis was tested that this existing classification system was predictive of yield and quality. Another hypothesis was also considered, that other selected physical factors could be more highly predictive of yield and quality. The selected physical factors were soil type and the depth of the cultivated layer. These hypotheses were tested by simple and multiple regression analysis (linear case only), and selected variables were plotted on graphs for visual examination.

CONCLUSIONS

Conclusions based on the testing of the hypotheses are as follows:

(1) Lane's classification system is not consistently predictive of yield and quality of tobacco within the study area.

(2) The ranking of soil types has been shown to

be consistently predictive of yield and quality.

(3) Under certain seasonal conditions, the depth of the cultivated layer will be a factor in predicting yields of tobacco.

OBSERVATIONS

Lane's Classification System is clearly heavily reliant on his assessment of the drainage characteristics of soils. It is the data for the drainage factor which are predictive of yields in 1960 but not in 1962, and are also predictive of quality in 1962. This drainage factor is in reality a complex variable. Drainage is associated with soil structure. The texture and structure of the various soil horizons determine to a large degree the quantity of water which moves through the profile of the soil.[3] Soil structure has associated with it at least two factors, drainage and aeration.

Returning to the problem of extreme seasonal variation in the predictive capacity of the classification system, it can be seen that if the drainage factor is to be predictive it must have water. In other words, if there is little rainfall the drainage factor will not be able to function as a variable. On the other hand, if there is too much rainfall, and the soils approach the state of supersaturation, the variable will again be incapable of prediction. This appears to be the case in the 1962 season, either too little, or

---

[3] H. O. Buckman, The Nature and Properties of Soils, New York, p 185.

too much rainfall has fallen.*

There is an additional complication. The tobacco plant requires varying amounts of rainfall during critical periods of its growth. For example, it is desirable that there be little rainfall shortly after it is planted in the field in order that a deep root is formed. For a few weeks after this critical period an overabundance of rainfall may not greatly affect plant growth. Thus, if average seasonal rainfall were to be considered as a variable, it would have little use since it would not reflect the amount of rainfall which fall within the critical periods of plant growth.

Accordingly, if Lane's classification system is to be more predictive of tobacco yield, rainfall should be considered as a variable; but average seasonal rainfall data is not suitable. Data for potential rainfall during the critical periods would have to be evaluated and then the percentage possibilities of critical amounts falling in particular years during the important stages of plant growth could be assessed. Using this percentage possibility of the occurrence of this rainfall during critical growth periods, and assuming the importance of rainfall to the classification system, a relatively accurate assessment of the predictive capability for Lane's classification system could be worked out.

Drainage is associated with the structure of the soil, and the structure of the soil is associated with such other factors as aeration. Since it would appear that the drainage factor did not

---

* That is, rainfall in an area may be assessed according to a spectrum ranging from aridity, to semi-aridity, through saturation to super-saturation. With aridity there would be too little rainfall for differences in drainage capacities in the various soils to make any difference in yields. With super-saturation the soils would be temporarily water-logged so differences in drainage capacity would make little difference. This could occur during a continuous rainfall, during a "wet" season.

function in 1962, but the data associated with the drainage factor were predictive of quality, it might be speculated that the quality of tobacco is not associated with the ability of the soil to drain water, but that it is associated with some other factor related to soil structure. This may be the aeration.

Soil series are established on the basis of profile characteristics through a study of the various horizons as to number, order, thickness, texture, structure, color, and so on. Soil types are named on the basis of differences of textures of the A horizon within the soil series. Thus the ranking of soil types encompasses all the factors utilized by Lane in his classification system, except the topographic factor (the topographic factor may be encompassed if soil phases are ranked within the soil types). Consequently, the reasons for the intercorrelation of Rank III and Lane's classification system can be understood since both deal with the same material. The ranking of soil type encompasses many soil factors, which nevertheless are unique to it as a soil type. Its consistency in predictive capability appears to result from the fact that the soil structure, which is unique to the soil type, and which Lane is also measuring, is predictive of 1960 tobacco yields and 1962 quality data. It is predictive of 1962 yields because other soil factors, unique to it as a soil type, and unaccounted for by Lane, function as predictive variables when others do not function. Lane's classification system is obviously lacking a variable that the soil type, as an all inclusive variable, contains.

The ranking of soil types, it has been shown, is consistent in its prediction of both yield and quality. A correlation was made between yield and quality data, and r was found to equal .65. Consequently it would seem that those soil types which produce the best yields of tobacco, also tend to produce the best quality.

During the tests, Norfolk County soil data, as provided by the Norfolk County Soil Map, was felt to be inadequate as being representative of the existing soil types. This suggests two possibilities: either the soil types assessed for the Norfolk County Soil Map were incorrect, or the soil types have changed over time. Table 5 illustrates the difference between the textural data provided by the soil map and the data provided by Lane. The soil map data indicate the presence of pure sands in the A horizons, while Lane has found no evidence of pure sands.

The Norfolk County Soil Map was published in 1928, about the year that the tobacco industry got started in this area. Many experienced tobacco farmers moved here at this time from the southern United States and from south-western Ontario. They were aware that tobacco soils required a great deal of fertilizers. The tobacco experimental station at Delhi recommends that 1200 pounds per acre of a combined fertilizer be added to the soils.[4] In addition,

---

[4] J. M. Elliot, Ontario Flue-cured Tobacco Soils, Guelph, p. 12.

considerable amounts of organic material must be added to replenish the soils each year. The inorganic residues from this organic matter would remain in the soils. This evidence of considerable amounts of inorganic material being added to the soils each year might suggest that the textural compostion of the tobacco soils has indeed changed from pure sands to loamy sands, through the addition of this material.

The depth of the cultivated layer has been shown to be predictive of tobacco yields under certain conditions. Since it is significantly predictive of yield when the classification system is not, it might be suggested that this factor could be employed in Lane's classification system to make it more consistently predictive of yield and quality.

The apparent increasing depth of the cultivated layer seems to be due to cultivation practices, and not to natural depositional processes. Evidence presented above of the considerable amounts of material added to the soils during cultivation, would tend to explain the sources of the increase.[5] If this is the case, the longer the farm is under cultivation, the deeper will be the depth of the cultivated layer. Since the depth of the cultivated layers is in certain seasons related to yields, it follows that the longer a farm has been under cultivation, the better the productive capacity it will have in terms of yields. It should be noted that the depth of of the cultivated layer is not a simple variable. This measure of

---

[5] Recent information indicates some farmers may level land by bulldozer, or may plough deeply once to break up a hard pan.

the depth of the cultivated layer may be actually measuring the physical thickness of the layer which itself may be a factor in influencing plant yield; or the data on physical thickness may be representative of increasing concentrations of chemical material such as nitrogen, that has accumulated due to cultivation practices.

In summation, it can be said that despite technical innovations in farming practices, the physical resources of the farm sites remain significant factors in the potential productive capacity of the farms.

BIBLIOGRAPHY

A. BOOKS

Buckman, H. O. The Nature and Properties of Soils, New York: MacMillan Co., 1966.

Haggett, H. Locational Analysis in Human Geography, London: Edward Arnold Ltd., 1965.

B. ARTICLES

Found, W. C. The Relation of the Distribution of Citrus to Soil Type and Winter Temperature in Orange County, Florida, Canadian Geographer, IX, 2, 1965.

Found, W. C. A Multivariate Analysis of Farm Output in Selected Land-Reform Areas of Jamaica, Canadian Geographer, XII, 1, 1968.

C. PUBLICATIONS

Klosler, G. Production Opportunities on Ontario Tobacco Farms, Guelph: University of Guelph, 1965.

MacGregor, M. A. Marketing Flue-Cured Tobacco in Ontario, Guelph: University of Guelph, 1966.

D. GOVERNMENT PUBLICATIONS

Elliot, J. M. Ontario Flue-cured Tobacco Soils, Ottawa: The Queen's Printer, 1959.

Experimental Farms Service, Flue-curing Tobacco in Ontario, Ottawa: Canada Dept. of Agriculture, 1958.

Ontario Dept. of Agriculture. 1967 Controls for Tobacco Insects and Diseases, Publication 298, 1967.

Ontario Dept. of Agriculture. Soil Survey of Oxford County, Guelph: Report No. 28, 1961.

Tobacco Harvesting Mechanization Committee Report. Tobacco Harvesting Mechanization, Toronto: Ontario Dept. of Agriculture, 1965.

Watson, M. C. Flue-cured Tobacco Production Practices for 1967, Ontario Dept. of Agriculture, 1967.

E. UNPUBLISHED MATERIAL

Ontario Flue-cured Tobacco Industry Inquiry Committee. Report, for the Minister of Agriculture for Ontario, 1964.

Vance. Tobacco Economy and People of the New Belt; M. A. Thesis. Western University of London Ontario, 1952.

LANE'S CLASSIFICATION
I

FARMER'S NAME ______________________

TOBACCO NUMBER ______________________

COUNTY ______________________

Township ______________________

VERY IMPORTANT

Year Tobacco Grown on Area Surveyed [illegible]

A GUIDE FOR THE CLASSIFICATION AND RATING OF TOBACCO SOILS

Department of Soil Science
Ontario Agricultural College

A. Physical Features (one description under each heading)

TEXTURE

0	Sandy Loam				
0	Loamy sand Lo Sand	✓			
0	Gravelly sandy loam				
15	Loam over gravel				
30	Loam over till				

TOPOGRAPHY

0	Level (0-5%)	✓			
15	Sloping (6-12%)				
30	Rolling (7-12%)				

DRAINAGE

0	Good	✓			
15	Mod. good				
30	Moderate				
45	Mod. poor				
60	Poor				

DEPTH TO CLAY

> 3 feet	✓			
2-3 feet				
< 2 feet				

EROSION

0	None	✓			
10	Moderate				
30	Severe				

DEPTH TO GRAVEL

> 3 feet	✓			
2-3 feet				
< 2 feet				

. Land Class

Add up the numbers which are opposite the descriptions you selected in Section A and subtract this figure from 100. Circle the land class below.

[✓ I]	II	III	IV	V	VI
[✓ 100 - 90]	85 - 75	70 - 60	55 - 45	40 - 30	25 or less

. Additional Information

1. (a) What % of land differs from B above 10%

(b) Why? Slopes & [illegible]

2. What is the (a) Topography Undulating to gently rolling

(b) Drainage Good

(c) Parent Material Medium to Coarse sand

(d) Depth to P. M. 2-2½ ft.

(e) Surface stoniness Few

(f) Depth of cultivated soil 7-9"

3. Is irrigation available YES ✓ or NO ______

4. Is tile drainage installed YES ______ or NO ✓

EROSION (wind or water)

None - no noticeable erosion (5-6" depth of cultivated layer)

Moderate - up to one-half of cultivated layer removed

Severe - most of cultivated layer removed

TOPOGRAPHY - refers to the lay of the land

Level (0-5% slopes) - level to gently undulating

Sloping (6-12% slopes) - gently sloping to rolling

Rolling (> 12% slopes) - strongly sloping; considerable slope and usually some irregularity.

III

LAND CLASSES FOR TOBACCO PRODUCTION

CLASS I (100-90)
Well-drained loamy sand
Depth to clay - 5 feet or more
Slope - level
e.g. Fox coarse sand
Fox fine sandy loam

CLASS II (85-75)
Moderately well-drained loamy sand
Well-drained sandy loam, gravelly sandy loam, very coarse sand
Depth to clay - 3 to 5 feet
Slope - 3 to 6%
Depth to gravel - 2-3 feet
e.g. Fox sandy loam
Fox gravelly sandy loam
Imperfectly drained loamy sand with tile drainage

CLASS III (70-60)
Imperfectly drained loamy sand
Moderately well-drained sandy loam
Well-drained loam
Depth to clay - 2 to 3 feet
Slope - level to undulating
Slope - 7-12%
Depth to gravel -- less than 2 feet
eg. Brady
Poorly drained loamy sand with tile drainage
Imperfectly drained sandy loam with tile drainage

CLASS IV (55-45)
Moderately poorly drained loamy sand
Imperfectly drained sandy loam
Depth to clay - less than 2 feet
Slope - level

CLASS V (40-30)
Poorly drained loamy sand
Moderately poorly drained sandy loam
Depth to clay - less than 2 feet
Slope - level
e.g. Granby

CLASS VI (25 or less)

EROSION (wind or water)
None - no noticeable erosion (5-6" depth of cultivated layer)
Moderate - up to one-half of cultivated layer removed
Severe - most of cultivated layer removed

TOPOGRAPHY - refers to the lay of the land

Level (0-2% slopes) - land is flat or very nearly so.
Sloping (3-6% slopes) - usually no abrupt change in steepness or direction of slope.
Rolling (7-12% slopes) - considerable slope and usually some irregularity.

APPENDIX 2

THE DATA

AMPLE ARMS	TEXTURAL DATA	DRAINAGE DATA	TOPOGRAPHY DATA	CLASS. LANE'S	DEPTH OF CULTIVATED LAYER	CLASS. LANE'S (CHECK)	RANK I
1	0.0	00.0	0.8	00.8	09.0	100.0	2.50
2	0.0	21.0	0.0	21.0	10.0	72.5	2.5
3	0.0	54.0	0.0	54.0	09.4	50.6	5.0
4	0.0	09.0	0.0	09.0	10.5	87.5	1.0
5	0.0	19.5	0.0	19.5	10.0	74.5	2.5
6	0.0	37.5	0.0	37.5	11.5	7.5	4.5
7	0.0	06.0	0.0	06.0	10.5	1.0	2.5
8	3.0	00.0	0.0	03.0	09.4	0.5	3.0
9	0.0	00.0	3.0	03.0	09.5	0.5	2.5
10	0.0	22.5	0.0	22.5	10.0	72.5	4.75
11	0.0	00.0	0.0	00.0	10.0	100.0	2.75
12	0.0	01.5	1.5	03.0	11.0	0.5	2.75
13	0.0	28.5	0.0	28.5	09.0	2.5	2.75
14	0.0	00.0	0.0	00.0	09.0	100.0	2.75
15	0.0	09.0	0.0	09.0	07.5	87.5	2.5
16	0.0	34.5	0.0	34.5	09.0	59.5	2.5
17	0.0	49.5	0.0	49.5	07.0	4.0	6.0
18	0.0	45.0	0.0	45.0	09.4	5.6	4.5
19	0.0	03.0	0.0	03.0	07.0	90.5	2.5
20	0.0	04.5	0.0	04.5	09.0	9.5	2.5
21	0.0	00.0	0.0	00.0	07.0	100.0	2.5
22	0.0	00.0	0.8	00.8	09.0	2.5	2.5
23	0.0	15.0	0.0	15.0	08.0	0.5	2.5
24	0.0	02.3	2.3	04.6	07.0	7.5	2.75
25	0.0	00.0	4.5	04.5	09.0	9.0	1.5
26	0.0	00.0	0.0	00.0	14.0	100.0	1.0
27	0.0	22.5	0.0	22.5	08.0	2.5	2.25
28	0.0	13.5	1.5	15.0	08.0	87.5	2.25
29	0.0	36.0	0.0	36.0	10.0	58.5	4.5
30	0.0	00.0	4.5	04.5	11.0	84.0	2.0
31	0.0	24.0	0.0	24.0	11.0	66.5	2.25
32	0.0	16.5	1.5	18.0	11.0	75.5	2.25
33	0.0	45.0	0.0	45.0	11.0	45.0	4.75
34	0.0	19.5	0.0	19.5	08.0	74.5	2.5
35	0.0	07.5	0.0	07.5	09.0	87.5	2.5
36	0.0	04.5	0.0	04.5	10.0	89.5	2.75
37	0.0	03.0	0.0	03.0	09.0	90.5	2.5
38	0.0	34.5	0.0	34.5	09.0	59.0	6.5
39	3.8	18.8	0.0	22.6	09.0	72.5	3.0
40	0.0	02.3	2.3	04.6	12.0	87.5	2.5
41	0.0	00.0	0.0	00.0	09.4	100.0	2.5

NORFOLK SOIL MAP SOIL TYPE	QUALITY	YIELD 1960	YIELD 1962	RANKED TEXTURE DATA	RANK III	RANK II
3.	49.31	2085.	871.	.1	2.	2.6
3.	54.24	1919.	2069.	.1	2.	2.6
5.	52.52	1770.	1616.	.1	2.	5.0
1.	50.84	1733.	1799.	.1	2.	1.0
3.	53.67	1665.	1469.	.1	4.	2.8
5.	48.51	1746.	1763.	.1	2.	4.6
2.	53.18	1943.	2201.	.1	2.	1.8
2.	53.22	1773.	1663.	.1	6.	2.0
2.	54.18	1963.	2168.	.1	4.	2.0
5.	55.17	1540.	1545.	.1	4.	4.8
2.	51.27	2080.	1243.	.1	3.	1.2
2.	51.05	1921.	1994.	.1	3.	1.9
2.	53.82	2030.	2073.	.1	3.	1.9
2.	52.83	2108.	1548.	.1	3.	1.9
2.	51.52	1702.	1578.	.1	2.	1.8
2.	47.20	1447.	1686.	.1	2.	1.8
6.	33.43	1154.	459.	.1	2.	5.6
5.	41.98	*	1907.	.1	2.	4.6
4.	46.09	1819.	1438.	.1	2.	3.6
4.	53.31	1611.	1804.	.1	2.	3.6
4.	52.95	*	1432.	.1	2.	3.6
3.	56.05	1569.	1867.	.1	4.	2.8
4.	53.29	1485.	1614.	.1	3.	3.7
4.	51.93	1531.	1188.	.1	4.	3.8
1.	49.76	1610.	1671.	.1	3.	1.1
1.	53.59	1834.	1825.	.1	2.	1.0
4.	53.75	1358.	1742.	.1	2.	3.6
4.	53.02	1496.	1714.	.1	2.	3.6
5.	40.44	1476.	599.	.1	4.	4.8
1.	53.04	1507.	1823.	.1	8.	1.6
4.	51.58	1601.	2107.	.1	2.	3.6
4.	52.52	1380.	1591.	.1	2.	3.6
5.	48.35	877.	1636.	.1	4.	4.8
4.	53.51	1667.	1594.	.1	4.	3.8
4.	51.48	1601.	1487.	.1	4.	3.8
3.	55.52	1983.	1939.	.1	3.	2.7
3.	58.18	1570.	2020.	.1	2.	2.6
5.	48.43	1420.	1646.	.1	4.	5.2
3.	53.67	1731.	1870.	.1	6.	3.0
1.	53.09	1638.	1637.	.1	4.	1.2
3.	48.43	1994.	1193.	.1	2.	2.6

*Data unavailable for 1960

APPENDIX 3

A PROJECTED STUDY OF TOBACCO FARM POPULATION MOVEMENT

In the course of the development of the classification system for predicting tobacco yield and quality, a futher examination was projected. Having developed a classification system, a study was suggested to determine to what extent tobacco farmers tended to gravitate toward these potentially more productive sites. To this end, the site selections made by the pioneering tobacco farmers could be determined, and then it would be possible to determine the length of time particular sites remained in tobacco production. It is hypothesized that the first tobacco farmers to enter the area, having the choice of any site in the whole area, would choose what they felt to be the best, or most potentially productive site. It is also hypothesized that a few of the early farmers may not have succeeded in selecting the best site, but that over time, through accumulated knowledge of the area, they would realize which were the most productive sites, and so tend to gravitate over time toward the better, or more productive sites.

A few measures of the tendency of farmers to locate on certain sites are derived, and a few tests have been carried out to determine the extent to which settlement patterns tend to concentrate around the potentially most productive tobacco producing areas.

A brief history of Norfolk County and tobacco growing in the area is in order. In the 1920's the area was agriculturally depressed.

Farmers were leaving, and conservation measures were being undertaken to reforest the area due to its apparent poor productive capacity. The soil conditions, however, were ideal for tobacco farmers. A tobacco industry had already developed in southwestern Ontario. Thus, when it was realized (about 1925) that this was potentially good tobacco growing area, many expert tobacco farmers were prepared to come into the area. Moreover, due to the abandonment of earlier forms of agriculture, there was little to impede the introduction of tobacco. In addition, papers indicate that the early methods of growing tobacco employed large plantations, and sharecroppers to work them. Later, sharecropping was slowly abandoned, and as a result, farms became smaller. Today, the Ontario Tobacco Marketing Board has ruled that no new tobacco farms may be brought into cultivation. With land at a premium, it is presumed it sold for a high price, and therefore further reduced the size of farms established. Consequently, the working hypothesis is that large farms will be found on the most productive sites, since they were the earliest farms and had the best sites to choose from, and that the smallest farms will be found on the least productive sites, since they were the last to be established and only the poorest tobacco land remained. A test is carried out comparing the size of the tobacco farms with the Rank III classification system.

It was speculated in the development of the classification system, that the depth of the cultivated layer was increasing due to massive fertilizer inputs. Papers indicate that tobacco farming practices are largely the same for most of the tobacco farmers. This is due largely to the delicacy and value of the crop. Consequently, it is hypothesized, that if farming practices are the same, and the same amount of fertilizer is added every year, differences in the depths of the cultivated layer will indicate the length of time that the farm site was under continuous cultivation. A test is carried out comparing the depth of the cultivated layer with the Rank III classification. This test is carried out to determine whether over time, farmers tended to sell their existing farms after a short period of time if they were located on poor sites and buy farms on better sites and remain for longer periods of time.

The two hypotheses deal with the location of the first tobacco farmers, that is, where they were established, and the later movement of farmers among the established farms. It is assumed that the size of farms is fixed once it is established. The establishement of the tobacco farm indicates the first choice of available tobacco land. Later the farmer could move, but the established farm size would remain permanently fixed.

The second hypothesis assumes that in some cases the farmer's first choice was not his ideal choice. It assumes he later left his first purchased, or established farm, and moved to a more productive farm. It also also assumes that the farmers who buy the smaller farms located on poorer soils, move to larger, better situated farms, and stay for longer periods of time. This length of time that the farmer stayed, it is hypothesized, is recorded in the depth of the cultivated layer.

The method of testing attempts to predict settlement patterns by relating these patterns to the sites which are classified in the foregoing section. Over time it is expected that concentrations of settlement patterns will be located near optimal available sites. The two variables which are employed to represent the settlement pattern are farm size (first choice of site) and depth of the cultivated layer (continuous use of site). Isopleth maps are drawn to illustrate the distribution of the size of farms, and the depths of the cultivated layer. Figures 5 and 17 show the isopleth maps. These isopleth maps are compared with a hypothetical settlement map of Norfolk County based largely on accessibility of sites developed by Colin H. Wood in a study of the area. His map is shown in Figure 18. The maps are compared to see if a settlement pattern is illustrated by the size of farms and by the depths of the cultivated layer.

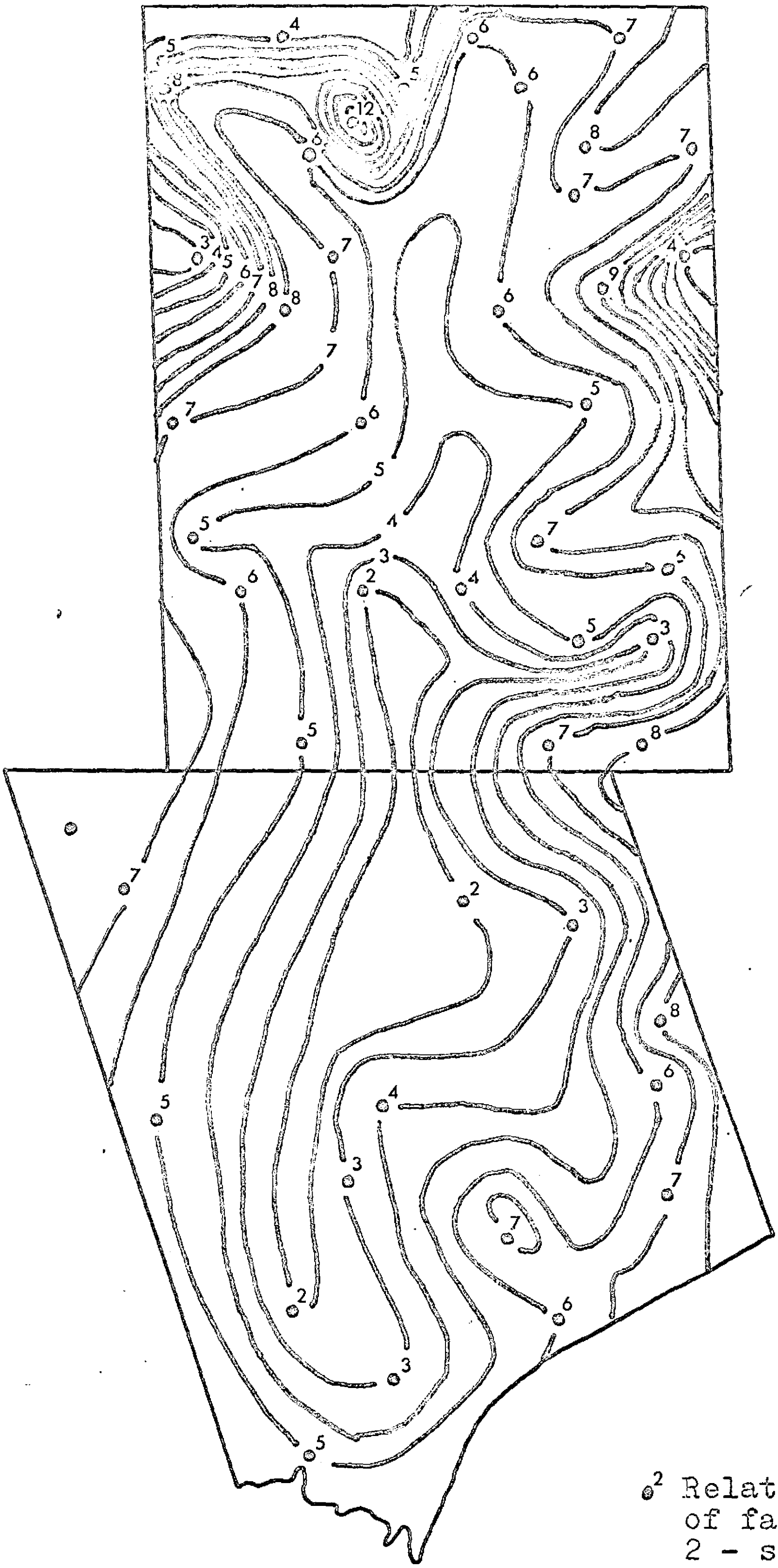
Data for size of the 41 farms are correlated in linear simple regression analysis with Rank III. The correlation with Rank III is $r = -.52$. Depth of the cultivated layer data are also correlated with Rank III. Here, $r = -.23$.

The isopleth maps appear to be similar. The largest farms generally appear to be on the periphery of the study area and the smaller farms in the centre. In the same way, the deepest depths of the cultivated layer occur on the periphery while the shallowest occur in the centre. Size of farms and depths of the cultivated layer correlate at -.01. This may be expected because as has been suggested, the first choice of site for establishment of the farm was not necessarily the best. The isopleth maps have a marked similarity to Wood's hypothetical settlement map. This suggests that accessibility to the farm site played an important part in where the tobacco farmers first settled, and later, where they tended to remain. This also suggests that records of size of tobacco farms, and data for the depths of the cultivated layer can be used as indicative of settlement patterms.

Lack of time prevents further pursuit of this analysis and few concrete conclusions can as yet be drawn as to the hypothesis that farmers will tend to locate over time on the most potentially productive sites. Many other tests are necessary.

In summary, the only significant correlation is between the size of farms and Rank III which tends to indicate that the first tobacco farmers in the area selected the better sites. The depth of the cultivated layer was not significantly associated with Rank III which tends to indicate that farmers did not remain on the better sites any longer than they remained on the poorer sites. This may be due to speculation that began as the Ontario Tobacco Marketing Board introduced agreage quotas, and finally closed tobacco farming to the outsiders who wished to establish tobacco farms. The isopleth maps show that distributions of size of farms and depths of the cultivated layer do not appear to be random. The size and depth of cultivated layer maps are similar. Both of them appear to be similar to Wood's hypothetical map of settlement pattern. This may suggest that tobacco farm location and continuous use is dependent on its accessibility to transportation routes.

FIG.17 ISOPLETH MAP ILLUSTRATING THE DISTRIBUTION OF FARM SIZES *

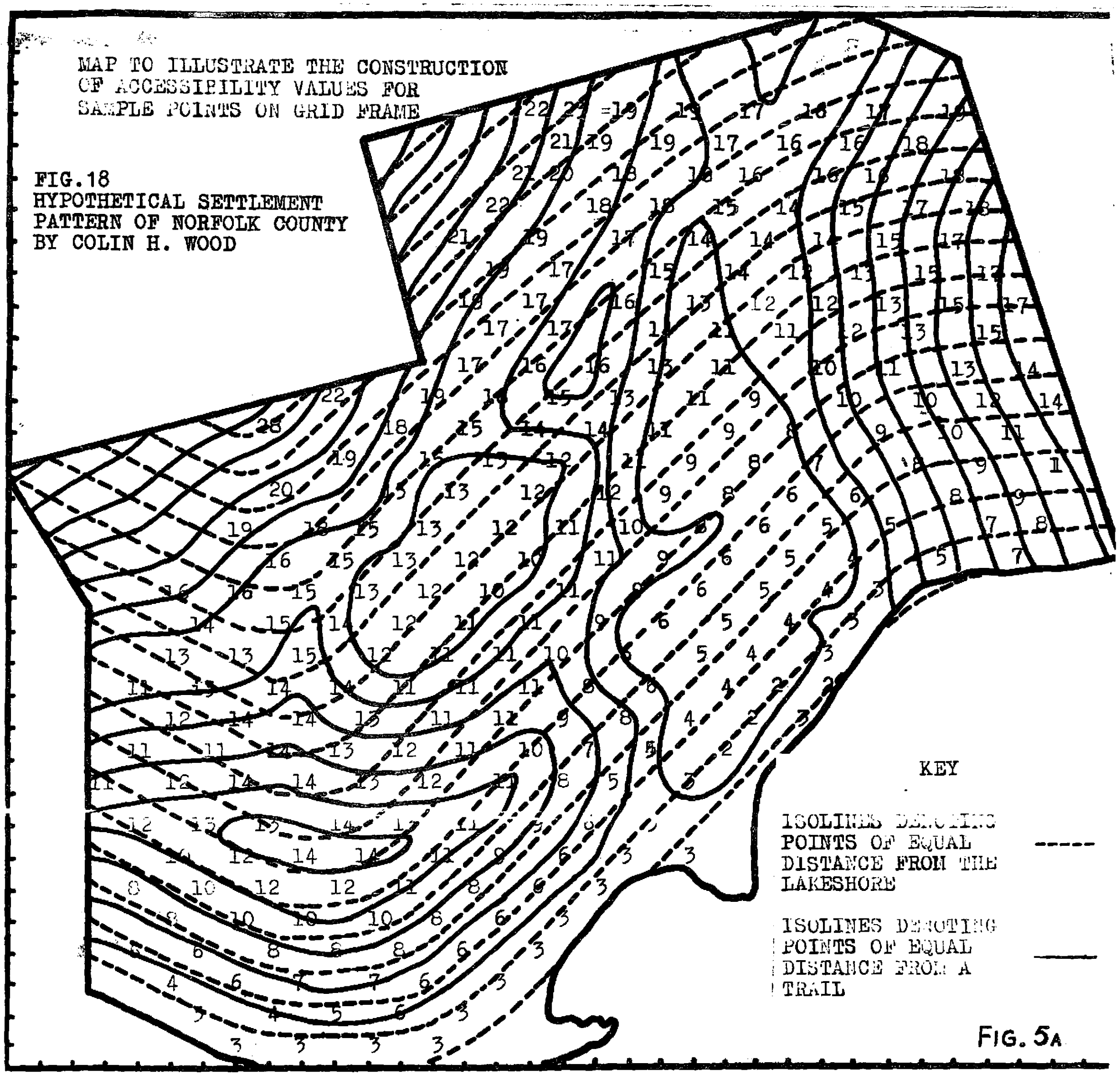


² Relative size
of farm
2 - smallest
12 - largest

*Data provided by Lane

MAP TO ILLUSTRATE THE CONSTRUCTION
OF ACCESSIBILITY VALUES FOR
SAMPLE POINTS ON GRID FRAME

FIG. 18
HYPOTHETICAL SETTLEMENT
PATTERN OF NORFOLK COUNTY
BY COLIN H. WOOD



KEY

ISOLINES DENOTING POINTS OF EQUAL DISTANCE FROM THE LAKESHORE	-----
ISOLINES DENOTING POINTS OF EQUAL DISTANCE FROM A TRAIL	———

FIG. 5A