AN ANALYSIS OF SOME OF THE FACTORS AFFECTING CROP YIELDS ON TWENTY-SIX CENTRAL MICHIGAN FARMS

Thesis for the Degree of M. S.

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This is to certify that the

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AN ANALYSIS OF SOME OF THE FACTORS AFFECTING

CROP YIELDS ON TWENTY-SIX CENTRAL

MICHIGAN FARMS

by

Robert Owen Kenworthy

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TABLE OF CONTENT

CHAPTER PAGE

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

DESCRIPTION OF THE PROBLEM

Predicting crop yields is one of the more difficult problems farmers have when making plans for the future. The information available for such predictions is in the form of average yields for states, crop reporting districts or type of farming areas. Another guide used in planning is "good standard" crop yields such as 25 percent above average[1]. This average varies from year to year for the same district or area. This year to year variation is primarily associated with weather conditions in the area during the growing season. Weather predictions for an entire growing season are difficult to make and present a problem to farmers attempting to estimate crop yields.

At some time during the process of farm planning an estimate of crop yields has to be made. This estimate, when based on the average yield for the state or area in which the farm is located, is not as accurate as is needed as a basis for a sound farm plan. The area or state average of crop yields is made up of yields from many different types of soil with a large range in cropping practices used.

A fairly accurate estimate of crop yields could be made for an individual farm if certain facts were known about the soil types on the farm and cropping practices used to raise crops.

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[1] "Farm and Home Planning, Part I, The Farm," Extension Service, Michigan State College, 1948.

In this study an attempt was made to devise a method to estimate crop yields. The information used for this estimate is soil type, slope, drainage, plant food added, humus maintenance and pH. Actual yield data was taken from fields for which the above information has been recorded.

Objectives of the Study

To devise a method for estimating crop yields for soils of different productive capacity. To determine crop yields using various levels of practices on soils of different productive capacity.

To study the amount of variation of crop yields on soil of different quality and the variation in yield as different levels of practices are used on soils of similar quality.

To study the variation in yields between crops to determine if any one crop varies more in its yield than any other crop.

To determine the proportion of each quality of soil used for different crops.

Another problem studied was the variation of crop yields. An attempt was made to determine the amount of variation of yield as practices varied. If variation in yield decreases as the practices under which the crop is grown are improved, the uncertainty associated with crop yield can be decreased.

When farmers use average yields as estimates of future production, uncertainty appears. If he applies inputs for average production and weather conditions are favorable, he has applied too

few inputs. Conversely if weather conditions are unfavorable he has applied too many inputs. Crop insurance does not always solve the problem for if he insures for low yield and yield is high he has lost his premium. Failure to insure when yield is low results in a loss of compensation.[2]

Malallocation of Resources Under Uncertain Conditions

With uncertain expectations the defects of resource allocation are of two types. 1. Using the expected mean of yield or price with these proving to be correct and, 2. using the expected mean of yield or price and these proving to be incorrect.

If the mean of prices or yield is used and they are correct and plans in anticipation of these values are made, the allocation of resources would not be in terms of the equating of marginal cost and returns. The producer, under most circumstances, desires to limit the anticipated dispersion of profit or losses. This desire and his subjective value of risk leads the producer to allocate his resources, not with maximization of profit as a sole guide but with due consideration of maintaining a certain degree of safety.

For example, a farmer would not add as much fertilizer to his corn as his resources would allow if he used all his resources for the single enterprise. This is due to the larger loss he may sustain if the price (or yield) expectations do not materialize. In

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[2] Heady, Earl O., Economics of Agriculture Production and Resource Use, Prentice-Hall, New York, 1952, pp. 439 - 445.

some cases expected yields do materialize and profits are lost because marginal costs and returns are not equated.

On the other hand, if the mean of prices (or yield) is used and it proves incorrect the malallocation of resources is even in greater error. It is obvious that under these conditions marginal cost and return cannot be equated. Also in this situation profit will not have been maximized.[3]

Hypotheses

There is a relation between crop yields, level of practices used and quality of soil on which the crops are grown.

The variation of crop yields, within a year, is greater on soil of poor productivity than on soil of good productivity.

The variation of crop yields, within a year, is greater on soil of similar quality, when poor practices are used than when good practices are used.

The amount of variation of yield is greater for corn and oats than for wheat and alfalfa within soil quality groups.

It is proposed that a production surface can be constructed by a statistical method to predict yields of crops on various qualities of soil using different levels of practices.

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[3] Johnson, D. Gale, Forward Prices for Agriculture, The University of Chicago Press, Chicago, Illinois, 1947, pp. 43 - 45.

It is proposed that the value of product and cost of production can be computed and from this the most profitable level of practices for different soil qualities can be found.

Problems Encountered in Defining Terms

An attempt has been made in this study to predict crop yields on the basis of soil quality and practices used in growing these crops.

Soil quality and many of the practices are observed in qualitative terms. It has been necessary to devise a scheme for assigning numerical values to such qualitative terms for statistical manipulations.

Another problem encountered was how to weight these factors, both for soil quality and for productive practices.

Definition of Soil Quality Index

Soil quality is defined in terms of the inherent capacity of the soil to produce. Three qualitative factors were considered in the construction of this index. They are soil type, slope and drainage - natural or artifical.

Each of these three factors was rated from 0.0 to 4.0 depending on its contribution to soil quality. (Zero denotes no contribution and 4.0 the highest possible.) These factors will be explained separately.

Soil Type. This is probably the most important factor of the three qualitative factors for constructing the soil quality index. The ratings for soil type generally follow the soil class of the soil type which denotes the texture[4] of the soil. Low ratings are generally given soil types with soil classes of loamy sands and sandy loams.[5] Higher ratings are given to soils with soil classes of loams and silt loams (Table I).

Slope. The rating for slope has the same parameter as soil type. The slope ratings follow the designations of slope given by the Soil Conservation Service, (Table II). Fields which did not fall into one category were rated by averaging the approximate percentage of land in each category. For example, a field having half of the land in a six percent slope and half in a zero percent slope, would be given a rating of 3.5.

Drainage. The ratings given drainage have the same parameters as the above two factors. This rating is not only more difficult to determine but also is more difficult to define. It probably is not as accurate as the rating for soil type and slope. This is due to

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[4] Texture refers to size of particles in the soil. The percent of sand, silt and clay determine the soil class name of a soil type. Millar, C. E. and Turk, L. M., Fundamentals of Soil Science, John Wiley and Sons, Inc., New York, pp. 39 - 45.

[5] The soil type name consists of two parts, soil series and soil class. Soil series identifies the area or place where the soil type was first found and mapped and soil class refers to the texture of the soil. For example, in the soil Miami loam, Miami is the soil series, loam is the soil class.

TABLE I

PRODUCTIVITY RATINGS FOR INDIVIDUAL MICHIGAN SOIL TYPES*

Index Rating			
0.0 to 1.0	1.1 to 2.0	2.1 to 3.0	3.1 to 4.0
Soil Type			
0.4 Plainfield Loamy Sand	1.1 Oshtemo Loamy Sand	2.1 Bronson Sandy Loam	3.3 Morley Silt Loam
0.5 Coloma Loamy Sand	1.2 Berrien Loamy Sand	2.1 Ogemaw Sandy Loam	3.3 Blount Silt Loam
0.6 Newton Loamy Sand	1.3 Oshtemo Sandy Loam	2.1 Metea Sandy Loam (I.D.)	3.3 Celina Loam
0.7 Ottawa Loamy Sand	1.3 Oshtemo Loamy Sand (I.D.)	2.3 Gilford Sandy Loam	3.5 Macomb Loam (Humic Gley)
0.8 Ottawa Sandy Loam (I.D.)	1.5 Oshtemo Sandy Loam (Humic Gley)	2.3 Brady Sandy Loam	3.5 Macomb Loam
0.9 Spinks Loamy Sand	1.8 Hodunk Sandy Loam	2.5 Hillsdale Fine Sandy Loam	3.5 Guelph Loam
	2.0 Bellefontain Sandy Loam	2.5 Warsaw Loam	3.5 Miami Loam
	2.0 Griffin Silt Loam	2.5 Fox Loam	3.6 Kawkawlin Fine Sandy Loam
	2.0 Fox Sandy Loam	2.5 Bellfontain Loam	3.7 Brookston Clay Loam
	2.0 Warsaw Sandy Loam	2.7 Gilford Loam	3.9 Conover Loam
	2.0 Hillsdale Sandy Loam	2.7 Locke Sandy Loam	3.9 Conover Silt Loam
		2.8 Kibbie Silt Loam	4.0 Brookston Loam
		3.0 Hillsdale Loam	4.0 Brookston Silt Loam

*Compiled by Ivan Schneider and Clarence Engberg, Department of Soil Science, Michigan State College.

TABLE II

RATINGS FOR SLOPE USED IN DETERMINING SOIL QUALITY

	Rating			
	0.0 - 1.0	1.1 - 2.0	2.1 - 3.0	3.1 - 4.0
Slope in percent	over 18	12 - 18	6 - 12	0 - 6

the fact that difficulty was encountered when trying to define drainage. The ratings and definition for drainage are given in Table III.

TABLE III

RATING FOR DRAINAGE USED IN DETERMINING SOIL QUALITY

	Rating			
	0.0 - 1.0	1.1 - 2.0	2.1 - 3.0	3.1 - 4.0
Explanation	Very wet the year around	Poorly drained wet runs and areas which always delay operations until too late to put in crop at the proper time. Crop frequently drowns out completely	Imperfectly drained wet runs that frequently delay tillage operations. Crop production is frequently hampered by wet conditions	Well drained naturally or artifically

An attempt has been made to combine the three factors which determine soil quality into an "index of soil quality." This was done by calculating the cube root of the product of the three factors, (Table IV). The product of the three factors was used rather than the sum so that the factor with the lowest index was dominant in determining the index. For example, a field with very poor drainage which could not be used for agricultural purposes would have a drainage factor of zero which would make the entire soil quality index equal to zero, even though the slope factor and soil type factor were each estimated at four.

Equal weight has been given each of the three factors used in calculating the soil quality index. This may or may not be the correct procedure to use in the construction of an index of this type. One of the alternatives considered when forming this index was using only soil type as a measure of quality. Comparison of the soil quality index and type for estimating yield will be considered in the statistical section of this study.

Definition of Productive Practice Index

This is the term used to describe the more important cultural practices used by farmers in producing crops. This index is based on three factors: plant food added, humus additive practices and pH. Other practices such as type of tillage, seed used, seed treatment and time of planting were omitted due to difficulty of measurement and unavailability of this type of data.

TABLE IV

COMPUTATION OF SOIL QUALITY INDEX*

Factor observed	Rating: 0.0 to 1.0	1.1 to 2.0	2.1 to 3.0	3.1 to 4.0
Soil Type (S_1)	0.4 Plainfield Loamy Sand	1.1 Oshtemo Loamy Sand	2.1 Bronson Sandy Loam	3.3 Morley Silt Loam
	0.5 Edwards Muck	1.2 Berrien Loamy Sand	2.1 Ogemaw Sandy Loam	3.3 Blount Silt Loam
	0.5 Coloma Loamy Sand	1.3 Oshtemo Sandy Loam	2.1 Metea Sandy Loam (I.D.)	3.3 Celina Loam
	0.6 Newton Loamy Sand	1.3 Oshtemo Loamy Sand (I.D.)	2.3 Gilford Sandy Loam	3.5 Macomb Loam
	0.7 Ottawa Loamy Sand	1.5 Oshtemo Sandy Loam	2.3 Brady Sandy Loam	3.5 Macomb Loam (Humus Gley)
	0.8 Ottawa Sandy Loam (I.D.)	1.5 Oshtemo Sandy Loam (Humus Gley)	2.5 Hillsdale Fine Sandy Loam	3.5 Guelph Loam
	0.9 Spinks Loamy Sand	1.8 Hodunk Sandy Loam	2.5 Warsaw Loam	3.5 Miami Loam
		1.8 Bellefontain Sandy Loam	2.5 Fox Loam	3.6 Kawkawlin Fine Sandy Loam
		2.0 Carlisle Muck	2.5 Bellefontain Loam	3.7 Brookston
		2.0 Griffin Silt Loam	2.7 Gilford Loam	3.9 Conover Loam
		2.0 Fox Sandy Loam	2.7 Locke Sandy Loam	3.9 Conover Silt Loam
		2.0 Warsaw Sandy Loam	2.8 Kibbie Silt Loam	4.0 Brookston Loam
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		2.0 Warsaw Sandy Loam	2.8 Kibbie Silt Loam	4.0 Brookston Loam
		2.0 Hillsdale Sandy Loam	3.0 Hillsdale Loam	4.0 Brookston Silt Loam

TABLE IV (continued)

COMPUTATION OF SOIL QUALITY INDEX*

Factor observed	Rating			
	0.0 to 1.0	1.1 to 2.0	2.1 to 3.0	3.1 to 4.0
Slope (S_2)	Over 18 percent	12 - 18 percent	6 - 12 percent	0 - 6 percent
Drainage (S_3)	Very wet year around	Poorly drained wet runs and areas which always hold up operations until too late to put in crop at proper time. Crop frequently drowns out completely	Imperfectly drained wet runs that frequently hold up tillage operation and frequently crop production is hampered by wet condition	Well drained naturally or artifically

*Soil Quality Index = $\sqrt[3]{S_1 \cdot S_2 \cdot S_3}$

<u>Plant Food</u>. The ratings for this index have the same parameters as that of the soil index. Ratings for various amounts of plant food added are given in Table V.

TABLE V

RATING FOR VARIOUS AMOUNTS OF PLANT FOOD ADDED PER ACRE PER YEAR

Code for Plant Food Added			
Rating	Pounds Plant Food	Rating	Pounds Plant Food
0	0	2.1	105
0.1	5	2.2	110
0.2	10	2.3	115
0.3	15	2.4	120
0.4	20	2.5	125
0.5	25	2.6	130
0.6	30	2.7	135
0.7	35	2.8	140
0.8	40	2.9	145
0.9	45	3.0	150
1.0	50	3.1	155
1.1	55	3.2	160
1.2	60	3.3	165
1.3	65	3.4	170
1.4	70	3.5	175
1.5	75	3.6	180
1.6	80	3.7	185
1.7	85	3.8	190
1.8	90	3.9	195
1.9	95	4.0	200
2.0	100		

Humus Maintenance. For the calculation of humus maintenance, Ohio Extension Bulletin 175[6] was used. Crops were rated with plus or minus values depending on whether they added to or depleted the soil. For example row crops, grains and annual grasses have a depleting effect on the soil so negative values were given these crops. Slope was also considered in this Bulletin. The steeper the slope the greater was the depletion. The soil building crops, alfalfa, clover and perennial grasses were given positive ratings. Fertiliser, manure and green manure were also given positive ratings.

In the calculation of humus maintenance in this study, the additive practice, manure per ton was changed from 0.15 to 0.30. This was done because in Ohio Extension Bulletin 175, the main consideration for manure being added was for plant food. In this index (humus maintenance) it is assumed that the humus added by manure is more important than the plant food added. Slope was omitted in the calculation of humus maintenance in this study because it was included in the soil quality index. Various values of humus maintenance and their rating are given in Table VI. A sample calculation of the humus maintenance index is given in Table IX.

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6 Salter, R.M., Lewis, R. D. and Slipher, J. A., "Our Heritage, the Soil," Ohio Extension Bulletin 175, April 1936. Soil depleting crops are given a negative value and soil building crops are given a positive value. These values are added over the five year period which give the value of humus maintenance.

TABLE VI

RATING GIVEN TO HUMUS MAINTENANCE VALUES AS AN AVERAGE OF THE FIVE YEAR PERIOD ON SOUTH CENTRAL MICHIGAN FARM, 1948 - 1952

Rating	Value	Rating	Value
0.0	- 9.0	2.1	- 1.65
0.1	- 8.65	2.2	- 1.30
0.2	- 8.30	2.3	- 0.95
0.3	- 7.95	2.4	- 0.60
0.4	- 7.60	2.5	- 0.25
0.5	- 7.25	2.6	+ 0.10
0.6	- 6.90	2.7	+ 0.45
0.7	- 6.55	2.8	+ 0.80
0.8	- 6.20	2.9	+ 1.15
0.9	- 5.85	3.0	+ 1.50
1.0	- 5.50	3.1	+ 1.85
1.1	- 5.15	3.2	+ 2.20
1.2	- 4.80	3.3	+ 2.55
1.3	- 4.45	3.4	+ 2.90
1.4	- 4.10	3.5	+ 3.25
1.5	- 3.75	3.6	+ 3.60
1.6	- 3.40	3.7	+ 3.95
1.7	- 3.05	3.8	+ 3.05
1.8	- 2.70	3.9	+ 4.65
1.9	- 2.35	4.0	+ 5.0 or more
2.0	- 2.0		

<u>Soil Acidity (pH)</u>. For the factor pH, ratings from 0.0 to 4.0 were given pH values from 4.5 to 7.5, Table VII. The productive practice index was calculated by taking the cube root of the product of the three individual factors - plant food added, humus maintenance and pH. Table VIII shows the entire productive practice index.

TABLE VII

RATING GIVEN TO pH VALUES USED TO CALCULATE PRODUCTIVE PRACTICE INDEX

Rating	pH value	Rating	pH value
0	4.50	2.1	6.07
0.1	4.57	2.2	6.15
0.2	4.65	2.3	6.22
0.3	4.72	2.4	6.30
0.4	4.80	2.5	6.37
0.5	4.87	2.6	6.45
0.6	4.95	2.7	6.52
0.7	5.02	2.8	6.60
0.8	5.10	2.9	6.67
0.9	5.17	3.0	6.75
1.0	5.25	3.1	6.82
1.1	5.32	3.2	6.90
1.2	5.40	3.3	6.97
1.3	5.47	3.4	7.05
1.4	5.55	3.5	7.12
1.5	5.62	3.6	7.20
1.6	5.70	3.7	7.27
1.7	5.77	3.8	7.35
1.8	5.85	3.9	7.42
1.9	5.92	4.0	7.50
2.0	6.00		

TABLE VIII

COMPUTATION OF PRODUCTIVE PRACTICES INDEX*

Factor observed	Index Rating 0.0 to 1.0	1.1 to 2.0	2.1 to 3.0	3.1 to 4.0
(P_1) Plant food added Average of five years per acre	Fertilizer and manure added 0 to 50 pounds of plant food	Fertilizer and manure added 51 to 100 pounds of plant food	Fertilizer and manure added 101 to 150 pounds of plant food	Fertilizer and manure added 151 to 200 or more pounds of plant food
(P_2) Humus additives practices**	- 9.0 to - 5.50	- 5.49 to - 2.0	- 1.99 to + 1.50	+ 1.51 to + 5.0 or more
(P_3) pH Level	pH 4.5 to 5.3	pH 5.4 to 6.0	pH 6.1 to 6.7	pH 6.8 to 7.5

*Cropping practice index = $\sqrt[3]{P_1 \cdot P_2 \cdot P_3}$

** Adapted from Salter, R. M., Lewis, R. D. and Slipher, J. A., "Our Heritage, The Soil," Ohio Extension Bulletin 175, April, 1936. However, the additive practice of commercial fertilizer was omitted due to its inclusion in P_1 and additive practice, manure, per ton, was changed from 0.15 to 0.30.

CHAPTER II

NATURE OF DATA USED

Collection of Data

Twenty-six farms in the counties of Ingham, Eaton, Barry, Clinton, Shiawassee, Genessee, Ionia and Livingston were selected for the study (Figure 1). An effort was made to include as many soil types as possible and the sample was limited to farms on which dairying was the main enterprise.

All the data available were taken from the Farm Account Records before the field work was started. The farm operators were interviewed for additional information regarding their practices to supplement material from the farm records.

The data needed for this study were collected on individual fields rather than farms in their entirety or by soil type. It was assumed that this was where farmers' problems lie when considering soil management and land use decisions. Questions were in the direction of "What should be done with particular fields?" The data were not taken on particular soil types because most fields on farms in the area studied have more than one soil type.

Due to the complexity of the data needed for this study a purposive sample of farms was chosen. The farms included were those on which records had been kept in cooperation with the Department of Agricultural Economics for the years 1948 - 1952. These had maps of their farms in their Farm Account Books showing the crops grown on

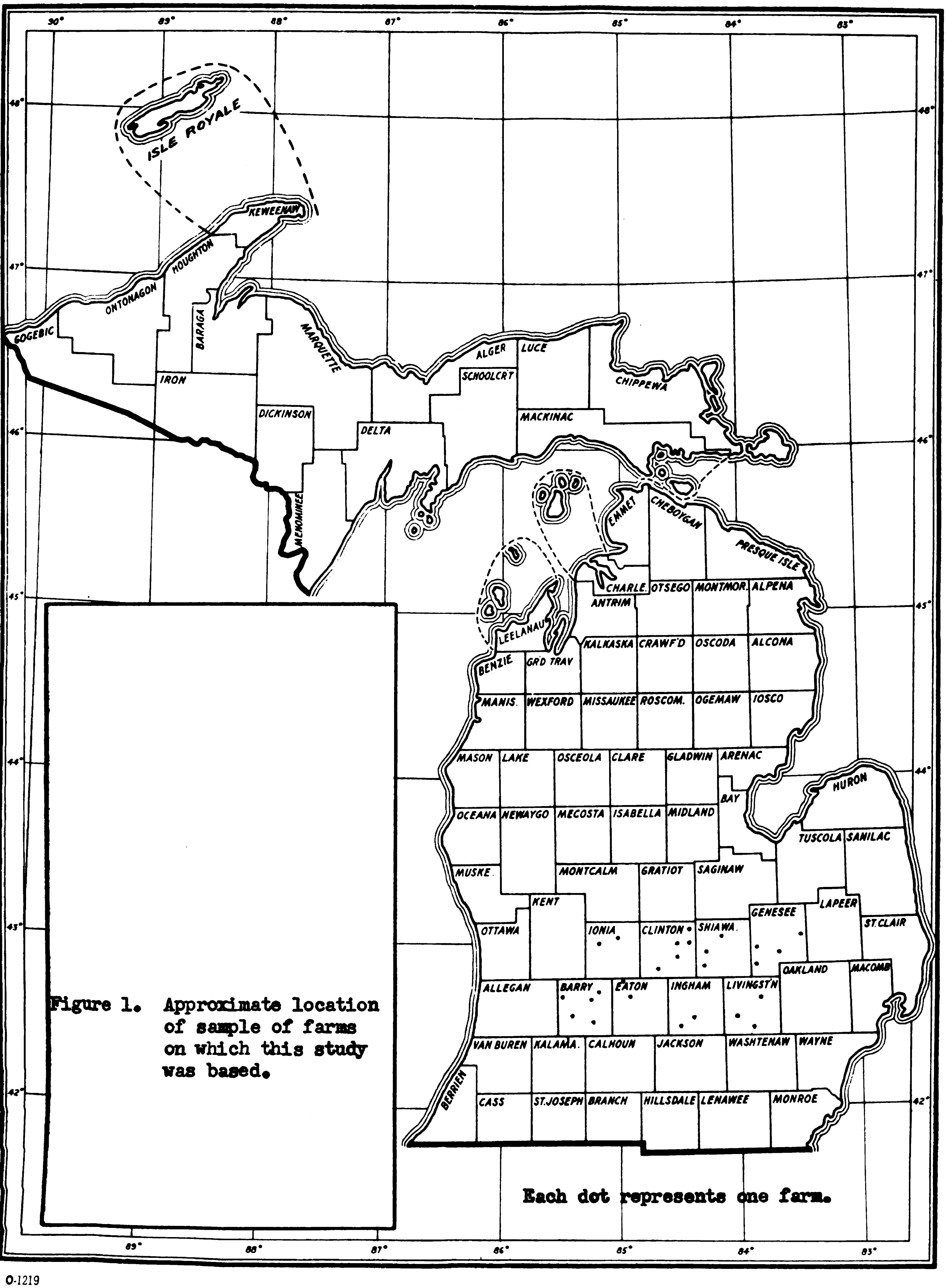

Figure 1. Approximate location of sample of farms on which this study was based.

Each dot represents one farm.

O-1219

each field over the five year period. Crop yields for each field must have been recorded in order to determine the yield per acre. Relatively few farm account cooperators record data in the detail needed for this study.

Soil type and slope of each field were taken from land use maps prepared by the Soil Conservation Service. Drainage was determined by inspection of each field by the writer and discussion with the farm operator.

The amount of plant food added per acre was determined by the amount and analysis of fertilizer added each year over the five year period plus 25 pounds of plant food[1] per ton of manure applied. The total pounds of plant food applied per acre was determined and divided by five to obtain the annual average for the field[2].

The value for humus maintenance was determined by adding the values given for crops in Ohio Extension Bulletin 175, plus 0.3 for each ton of manure per acre plus the value of green manure crop plowed down. See Table IX for a sample calculation.

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1 Millar, C. E., Turk, L. M., Fundamentals of Soil Science, New York, John Wiley and Sons, Inc., p. 219. "On the average a ton of manure contains about 25 pounds of plant nutrients. (Ten pounds Nitrogen, five pounds Phosphorus and ten pounds Potassium.)"

2 For example if for a five year period 600 pounds of 4-16-16, 200 pounds of 10-10-10 and twelve tons of manure per acre were added, the total pounds of plant food added is 576 and the average for the five year period is 115 pounds per acre. This is rated at 2.3, Table V.

TABLE IX

SAMPLE CALCULATION FOR DETERMINING HUMUS MAINTENANCE
FOR A FIELD OVER A FIVE YEAR PERIOD*

Crop grown	Humus maintenance value	Green manure crop	Humus maintenance value	Manure ton per acre	Humus maintenance value
Corn	- 2.0	Alfalfa	+ 2.5	10	3.0
Oats	- 1.0	plowed			
Wheat	- 1.0	down			
Alfalfa first year	+ 2.5				
Alfalfa second year	+ 0.5				

*Value of humus depletion equals - 4.0 and value of humus added equals 8.5. The humus maintenance value for the field is + 4.5. This is rated at 3.9, Table VI.

The pH for each field was determined by test with a Soiltex kit[3] and lime application for the five year period was recorded.

Description of Data

The distribution of the acreage and percent of total land used for each crop in each soil group included in the study is given in Table X. On these farms nearly 57 percent of the land was in the 3.1 - 4.0 soil quality group. Nearly 44 percent of the total land

[3] This is an indicator solution with two indicators, (Aurin and Brome Cresol green) dissolved in Ethyl alcohol and distilled water. The solution is slightly acid.

TABLE X

DISTRIBUTION OF 15,600 ACRES IN SOIL CLASSES AND CROPS ON TWENTY-SIX CENTRAL MICHIGAN FARMS, 1948 - 1952

Crop	Soil Classes								Total acres	Percent of Total
	0.0 - 1.0		1.1 - 2.0		2.1 - 3.0		3.1 - 4.0			
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent		
Wheat	20	1.0	170	8.6	612	31.0	1 173	59.4	1 975	12.7
Spring grain	46	1.8	391	15.0	580	22.4	1 582	60.8	2 599	16.7
Corn	17	0.5	568	17.2	901	27.3	1 816	55.0	3 302	21.1
Other row crops*					12	5.9	192	94.1	204	1.3
Hay and grass silage	80	2.2	723	20.4	696	19.7	2 043	57.7	3 542	22.7
Perennial pasture	96	2.9	730	22.0	792	23.9	1 696	51.2	3 314	21.2
Annual pasture			47	15.2	85	27.5	177	57.3	309	2.0
Miscellaneous**			54	15.2	149	42.0	152	42.8	355	2.3
Total acres	259	1.7	2 683	17.2	3 827	24.5	8 831	56.6	15 600	100.0

*Includes Sugar Beets, Soybean and Beans

**Includes Summer Fallow, Buckwheat, Summer seeding and Clover Seed on these farms was in hay and pasture, 21 percent in corn and over 29 percent in small grain.

Table XI shows the percent of land used for each crop in each soil group. The percent of land in hay and pasture showed a general increase as soil quality decreased. The percent of land in spring grain was about the same for all soil classes. The percent of land in corn was about the same in the top three soil groups and falls sharply in the lowest group. Wheat was grown almost exclusively on soil in the top two soil groups.

Nearly 70 percent of the land in the lowest soil group was in hay and pasture while 42 percent of the land in the top soil group was in hay and pasture. Fourteen percent of the land in the lowest soil group was in wheat and corn and in the top soil group 33 percent of the land was in these two crops.

TABLE XI

PERCENT OF LAND IN VARIOUS CROPS IN EACH SOIL CLASS ON TWENTY-SIX CENTRAL MICHIGAN FARMS, 1948 - 1952

Crop	Soil Quality Index							
	0.0 - 1.0		1.1 - 2.0		2.1 - 3.0		3.1 - 4.0	
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Wheat	20	7.7	170	6.3	612	16.0	1 173	13.3
Spring grain	46	17.8	391	14.6	580	15.1	1 582	17.9
Corn	17	6.6	568	21.2	901	23.6	1 816	20.6
Other row crops					12	0.3	192	2.2
Hay and grass silage	80	30.9	723	26.9	696	18.2	2 043	23.1
Perennial pasture	96	37.0	730	27.2	792	20.7	1 696	19.2
Annual pasture			47	1.8	85	2.2	177	2.0
Miscellaneous			54	2.0	149	3.9	152	1.7
Total	259	100.0	2 683	100.0	3 827	100.0	8 831	100.0

CHAPTER III

ANALYSIS OF DATA

Effect of Practices on Yields of Crops Grown on Soils of Similar Quality

The yield index[1] for the main crops grown was calculated for groups of productive practices for each soil group, Table XII. Due to the lack of data for the productive practice groups 3.1 - 4.0 and 0.0 - 1.0, the fields were divided into two groups according to productive practices (2.1 - 4.0 and 0.0 - 2.0) and the yield index was calculated, Table XIII.

There were small differences in the yield of wheat, especially when similar practices were used on the two top soil groups. Yield of wheat dropped sharply when grown on soil type 1.1 - 2.0.

Considering the difference in yield of wheat grown on fields in the top soil group, it can be seen that good practices increase yield thirteen index points over the lower group. On the 2.1 - 3.0 soil group good practices increased the yield six index points over the poor practices. This may indicate that more response was derived from good practices on good soil than from good practices on soil

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[1] Yield index was calculated on a yearly basis to reduce the variability of the index due to different weather conditions for each year. The average for each year for each crop was found and set equal to 100. The index was calculated by dividing the individual observations by the average and multiplying the result by 100.

TABLE XII

YIELD INDEX OF WHEAT, OATS, CORN, HAY AND THEIR AVERAGE CALCULATED FOR SOIL INDEX AND PRODUCTIVE PRACTICE GROUPS GROWN ON THE SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Index															
	3.1 - 4.0				2.1 - 3.0				1.1 - 2.0				0.0 - 1.0			
	Practice Index				Practice Index				Practice Index				Practice Index			
	3.1 to 4.0	2.1 to 3.0	1.1 to 2.0	0.0 to 1.0	3.1 to 4.0	2.1 to 3.0	1.1 to 2.0	0.0 to 1.0	3.1 to 4.0	2.1 to 3.0	1.1 to 2.0	0.0 to 1.0	3.1 to 4.0	2.1 to 3.0	1.1 to 2.0	0.0 to 1.0
Crop	Yield Index															
Wheat	110	105	94	78	133	99	100	85			75	55				
Oats	115	109	101	57	83	85	86	75		80	47	68				
Corn	115	112	96	110	62	85	92	71		61	46					
Alfalfa hay	101	101	105	72	124	113	99	39		57	62	55				
Number of observations	52	291	162	22	26	83	90	31		7	8	10				
All crop average	110	107	100	76	111	94	94	63		67	61	60				

TABLE XIII

CROP YIELD INDEX FOR WHEAT, OATS, CORN, HAY AND THEIR AVERAGE FOR SOIL QUALITY GROUPS AND PRODUCTIVE PRACTICE GROUPS FOR THE SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Index					
	3.1 - 4.0		2.1 - 3.0		1.1 - 2.0	
	Practice Index		Practice Index		Practice Index	
	2.1 - 4.0	0.0 - 2.0	2.1 - 4.0	0.0 - 2.0	2.1 - 4.0	0.0 - 2.0
Crop	Yield Index					
Wheat	105	92	102	96		68
Oats	109	98	84	77		79
Corn	112	104	82	87		
Alfalfa	101	101	118	80	57	58
Average all crops	107	98	97	84	57	66

without a high inherent capacity to produce. Comparison cannot be made on soil group 1.1 - 2.0 due to lack of data.

For oats the response on the top soil group to good practices over poor practices gave a yield increase of eleven index points. In soil group 2.1 - 3.0 the increase of good practices over poor was only seven points. This also bears out the fact that the response to good practices on good soil was larger than the response to good practices on the 2.1 - 3.0 soil group. There was also a larger difference between yield of oats on similar practice groups of soil groups 3.1 - 4.0 and 2.1 - 3.0 than there was for wheat.

For corn the response to good practices on the top soil group was eight index points. In soil group 2.1 - 3.0 the good practice group had a lower yield index than the 0.0 - 2.0 practice group. No explanation can be made for this. The effect of good practices showed more response on good soil than it did on soil group 2.1 - 3.0.

For alfalfa the effect of good practices on soil group 3.1 - 4.0 shows no increase in yield over that of 0.0 - 2.0 productive practices. However, for soil group 2.1 - 3.0 good practices showed an increase of thirty-eight yield index points over that of 0.0 - 2.0. This large increase in yield and the lack of increase in yield in soil group 3.1 - 4.0 may be due to the difference in the number of cuttings of hay taken from the fields. A great deal of reliability should not be placed on the large increase in yield in group 2.1 - 3.0 or lack of yield increase in group 3.1 - 4.0. Also the lack of ability in measuring hay yields accurately was another factor.

The average of all crops shows a general decrease in yield index as soil quality goes lower and as poor practices are used.

Yield Variation Within Productive Practice Groups of Soil Groups

In order to determine the variation about the mean of yield index within productive practice groups for each soil group, the standard deviation[2] was calculated for the yields that are presented in Table XIII. This shows the mean of all the individual variations about the mean of the yield index and is presented in Table XIV.

For soil group 3.1 - 4.0 the standard deviations were larger for all crops for the poor practices, the greatest difference being for oats. For soil group 2.1 - 3.0 the standard deviation was larger only for alfalfa in practice group 0.0 - 2.0 when comparing productive practice groups.

Using the standard deviation to compare the amount of variation in productive practice groups did not give a completely accurate comparison due to different means in each group.

For a more accurate comparison of the amount of variation of yield for productive practice indexes of a soil group, the coefficient

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[2] Simpson, George and Kafka, Fritz, Basic Statistics, W. W. Norton Company, Inc., New York, p. 199. Formula used as $s = \sqrt{\frac{\Sigma x^2}{N}}$ where x^2 = squared deviation from mean and N = number of observations.

TABLE XIV

STANDARD DEVIATIONS FOR YIELDS OF WHEAT, OATS, CORN, AND HAY WITHIN SOIL QUALITY AND PRODUCTIVE PRACTICE GROUPS FOR SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Index					
	3.1 - 4.0		2.1 - 3.0		1.1 - 2.0	
	Practice Index		Practice Index		Practice Index	
	2.1 - 4.0	0.0 - 2.0	2.1 - 4.0	0.0 - 2.0	2.1 - 4.0	0.0 - 2.0
Crop	Standard Deviation					
Wheat	25.59	27.53	23.70	21.42		9.43
Oats	32.87	37.22	25.63	25.57		25.17
Corn	32.55	35.93	36.13	32.80		
Alfalfa	28.60	29.74	35.48	37.36	20.44	18.65

of variation[3] was calculated using the yield index and the standard deviation of yield for each group of practices within each soil group. This statistic (Table XV) in percent is the relative variation about the means of each group and can be used to compare variation between groups.

For soil group 3.1 - 4.0 (Table XV) the coefficient of variation was greater, for all crops and their average, on the low group of practices when compared to the high group of practices. For soil group 2.1 - 3.0 the variation was larger on the lower practices for oats, alfalfa and average of all crops. This shows a greater response in increasing yield when good practices are used on good soil (3.1 - 4.0 soil quality group) than when used on soil quality group 2.1 - 3.0. Lack of data prohibits reliable comparisons of yield variation in soil group 1.1 - 2.0.

In order to determine if there was any significant difference between average yields of each productive practice group within each soil group a "t" test[4] was used.

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[3] Ibid, p. 212. Formula used for calculation is $V = \frac{s}{\bar{X}} \times 100$ where V = coefficient of variation s = standard deviation and $\bar{X}$ = mean of the group of observations.

[4] Snedecor, George W., Statistical Methods, Iowa State College Press, Ames, Iowa, Chapter 4.

Formula used for calculation was $t = \dfrac{\bar{X}_1 - \bar{X}_2}{\sqrt{\dfrac{N_1 S_1^2 + N_2 S_2^2}{N_1 + N_2 - 2}} \times \sqrt{\dfrac{N_1 N_2}{N_1 + N_2}}}$

TABLE XV

COEFFICIENTS OF VARIATION (PERCENT) FOR YIELDS OF WHEAT, OATS, CORN, AND HAY FOR SOIL INDEX GROUPS AND PRODUCTIVE PRACTICE GROUPS ON THE SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Index					
	3.1 - 4.0		2.1 - 3.0		1.1 - 2.0	
	Practice Index		Practice Index		Practice Index	
	2.1 - 4.0	0.0 - 2.0	2.1 - 4.0	0.0 - 2.0	2.1 - 4.0	0.0 - 2.0
Crop	Percent					
Wheat	24	30	23	22		14
Oats	30	38	31	33		32
Corn	29	35	44	38		
Alfalfa	28	29	30	47	36	32
Average	28	30	32	36	36	27

Significant differences (Table XVI) were found for yields of wheat, oats and the average of all crops when the two groups of productive practices in soil group 3.1 - 4.0 were compared. In soil group 2.1 - 3.0 significant differences in yields of alfalfa and the average of all crops were found when comparing the yields of the two productive practices.

TABLE XVI

T VALUES FOR YIELDS OF WHEAT, OATS, CORN AND HAY TO DETERMINE SIGNIFICANCE BETWEEN PRODUCTIVE PRACTICE GROUPS WITHIN SOIL QUALITY GROUPS FROM THE SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Index	
	3.1 - 4.0	2.1 - 3.0
	Practice Indexes	Practice Indexes
	2.1 - 4.0 and 0.0 - 2.0	2.1 - 4.0 and 0.0 - 2.0
Crop	t	t
Wheat	2.63*	.76
Oats	1.99*	.99
Corn	1.77	- .55
Alfalfa		4.46*
Average	2.93*	3.20*

*Significant difference at 95 percent level

Yields Calculated for Soil Quality Groups with Productive Practices Not Considered

Analysis of yields for different soil quality groups was undertaken to determine differences between and variation within soil quality groups. The yield index (Table XVII) was calculated for each soil quality group.

TABLE XVII

YIELD INDEX FOR WHEAT, OATS, CORN AND HAY AND THEIR AVERAGE FOR SOIL QUALITY GROUPS ON SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Index			
	3.1 - 4.0	2.1 - 3.0	1.1 - 2.0	0.0 - 1.0
Crop	Yield Index			
Wheat	100	98		
Oats	106	102	70	
Corn	109	85		
Alfalfa hay	103	100	58	
Average all crops	105	96	65	

For wheat in the two top soil quality index groups there was only two yield index points difference. Oat yields between these two soil groups also have small differences with a sharp decrease in yield for soil group 1.1 - 2.0. Corn yields between the two soil groups had the greatest difference in yield index. Alfalfa hay yield difference was small for the top two soil quality groups

with a sharp decrease in yield for soil group 1.1 - 2.0. The average yield of all crops showed a decrease as soil quality decreased.

Variation of Yield Within Soil Groups and Comparison of Variation Between Soil Groups

In order to determine variation of yield within soil groups the standard deviation was calculated for crops by soil groups (Table XVIII). Standard deviations were larger for corn, alfalfa and average of all crops for soil groups 2.1 - 3.0 when compared to soil group 3.1 - 4.0.

TABLE XVIII

STANDARD DEVIATIONS FOR YIELDS OF WHEAT, OATS, CORN AND ALFALFA AND THEIR AVERAGE FOR SOIL QUALITY GROUPS FOR SAMPLE OF CENTRAL MICHIGAN FARMS 1948 - 1952

	Soil Index			
	3.1 - 4.0	2.1 - 3.0	1.1 - 2.0	0.0 - 1.0
Crop	Standard Deviation			
Wheat	27.00	20.97		
Oats	34.33	32.76		
Corn	33.75	34.28		
Alfalfa	29.42	40.87		
Average	31.19	34.27		

For a comparison of variation of yield between soil quality groups, the coefficient of variation was calculated for yields on soil quality groups (Table XIX). The coefficient of variation was larger at 2.1 - 3.0 for corn, alfalfa and average of all crops when compared with soil group 3.1 - 4.0. This means that yields in this group had a larger variation than when grown on soil quality group 3.1 - 4.0.

TABLE XIX

COEFFICIENT OF VARIATION OF CROP YIELD FOR WHEAT, OATS, CORN, AND ALFALFA AND THEIR AVERAGE FOR SOIL QUALITY GROUPS ON SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Index		
	3.1 - 4.0	2.1 - 3.0	1.1 - 2.0
Crop	Percent		
Wheat	27	21	
Oats	32	32	
Corn	31	40	
Alfalfa	29	41	
Average	30	36	

For determining significant difference in yield between soil quality group a "t" test was used (Table XX). Differences in yield of the two top soil groups were found to be significant for corn and average of all crops. For the two bottom soil quality groups

TABLE XX

T VALUES FOR CROP YIELDS OF WHEAT, OATS, CORN AND ALFALFA HAY AND THEIR AVERAGE ON SOIL QUALITY GROUPS FOR SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Index	
	3.1 - 4.0 and 2.1 - 3.0	2.1 - 3.0 and 1.1 - 2.0
Crop	t	t
Wheat	.42	
Oats	.75	10.52*
Corn	7.94*	
Alfalfa	.63	3.48*
Average	4.24*	3.22*

*Significant at 95 percent level

significant differences in yield were found for oats, alfalfa and average of all crops.

Yield Index and Variation of Yield Between and Within Soil Type Groups

An inspection of the data indicates that a yield index based on soil type alone could be made that compares favorably with the index based on the three factors of soil quality.

Yield index (Table XXI) when calculated for soil type and compared with yield index calculated with the soil quality index

TABLE XXI

YIELD INDEX FOR WHEAT, OATS, CORN, ALFALFA AND THEIR AVERAGE FOR SOIL TYPE ONLY ON SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Index			
	3.1 - 4.0	2.1 - 3.0	1.1 - 2.0	0.0 - 1.0
Crop	Yield Index			
Wheat	103	88	98	
Oats	110	84	76	
Corn	118	93	84	
Alfalfa	96	97	92	
Average	107	91	87	

(Table XVII) showed greater differences in yield between groups when calculated using soil type alone.

For wheat (Table XXI) there were fifteen yield index points difference between the two top soil groups and in Table XVII there are only two index points difference in yield. For soil 1.1 - 2.0 (Table XXI) the yield index was ten index points higher than that for soil groups 2.1 - 3.0.

These larger differences hold true when comparing yield index for soil quality and soil type index for all crops except alfalfa.

Coefficient of variations (Table XXII) shows variation generally increasing as soil type index goes lower, except in soil type group 0.0 - 1.0 where the number of observations was very small.

TABLE XXII

COEFFICIENT OF VARIATION FOR YIELD INDEX ON WHEAT, OATS, CORN, ALFALFA AND THEIR AVERAGE FOR SOIL TYPE GROUPS ON THE SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Index			
	3.1 - 4.0	2.1 - 3.0	1.1 - 2.0	0.0 - 1.0
Crop	Percent			
Wheat	23	35	21	
Oats	31	30	34	25
Corn	30	32	49	
Alfalfa hay	35	34	39	26
Average	28	33	38	26

When the "t" values were calculated for differences of yield using soil type only, (Table XXIII) and compared with Table XX which are "t" values for differences of yield using Soil Quality Index, it can readily be seen that there is more significant differences in yield when the index of soil type only is used. This may substantiate the fact that slope and drainage do not need to be included in the soil quality index.

TABLE XXIII

T VALUES FOR CROP YIELDS OF WHEAT, OATS, CORN, ALFALFA AND THEIR AVERAGE BETWEEN SOIL TYPE GROUPS ON THE SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Index		
	3.1 - 4.0 and 2.1 - 3.0	2.1 - 3.0 and 1.1 - 2.0	1.1 - 2.0 and 0.0 - 1.0
Crop	t	t	t
Wheat	3.08*	1.26	
Oats	4.51*	1.31	.28
Corn	4.33*	1.18	
Alfalfa	- .18	.71	13.36*
Average	6.06*	1.61	2.19*

*Significant difference at 95 percent level

However, the principal difficulty in omitting slope and drainage was in the case of an occasional field where either of these factors may cause a definite limitation to crop production.

Difference in Variation of Crop Yields for Various Crops Within Soil Groups and Productive Practice Groups

Smaller differences in yield (Table XIII) were obtained for wheat between similar practice groups for soil groups 2.1 - 3.0 and 3.1 - 4.0 than were obtained between these same groups for oats and corn. Alfalfa does not follow a pattern of reduction of yield which is probably due to differences in the number of cuttings taken.

Coefficients of variation (Table XV) are generally smaller for wheat and alfalfa than are the coefficients of variation for corn and oats when compared in the same soil quality and productive practice groups. Variation about the averages for wheat and alfalfa are generally smaller than the variations about the averages for corn and oats within individual practice and soil groups.

Comparison of Variation of Yield Among Crops Between Soil Quality Index Groups

Smaller yield index differences are noted (Table XVII) for wheat and alfalfa than for corn and oats between index groups 2.1 - 3.0 and 3.1 - 4.0.

Smaller coefficients (Table XIX) of variation are found for wheat and alfalfa in soil index group 3.1 - 4.0 than is found for corn and oats. However, in soil index group 2.1 - 3.0 wheat yield variation is the smallest and alfalfa yield variation is the largest. The alfalfa yield variation again may be due to different number of cuttings.

Comparison of Variation of Yield Between Crops on Soil Type Groups

Wheat and alfalfa yield indexes (Table XXI) show smaller differences between soil type groups than do those of corn and oats. It was noted that the yield index for wheat was higher for soil type 1.1 - 2.0 than for 2.1 - 3.0. No logical conclusion can be drawn.

No definite conclusion can be drawn from the coefficients of variation (Table XXII) except that the variations between soil type groups for alfalfa yield over all the soil type groups are more uniform than any of the other crops.

An Attempt to Fit a Yield Production Surface by Multiple Linear Regression

The formula to calculate the indexes for the production surface was $y = a + b_2 xz + b_3\sqrt{x} + b_4 z$ where x = productive practices index and z = soil index.

The method used for calculation was the Doolittle check sum.[5]

The resultant coefficients were:

$$b_2 = -\ 0.26592$$
$$b_3 = +\ 2.18413$$
$$b_4 = +\ 40.66642$$
$$a = -\ 29.03$$

and the "y" values (yield index) for various points on the surface are given in Table XXIV.

This calculation was based on the actual yield data collected for this study for corn only. The formula used to calculate yield index was purposely designed to show decreasing marginal and increasing total returns to productive practices for the soils of low inherent productive capacity. For the soils of high inherent productive

[5] Ezekiel, Mordecai, Methods of Correlation Analysis, Second edition, John Wiley and Sons, Inc., New York, 1941, pp. 198 - 203 and 461 - 465.

TABLE XXIV

YIELD INDEX CALCULATED BY LINEAR REGRESSION, DOOLITTLE CHECK SUM

	Soil Quality Index							
	3.5				2.5			
	Practice Index				Practice Index			
	3.5	2.5	1.5	0.5	3.5	2.5	1.5	0.5
Yield index	114.12	114.42	114.56	114.39	74.38	74.41	74.29	73.85
	1.5				0.5			
Yield index	34.64	34.41	34.02	33.31	-5.08	-5.58	-6.24	-7.22

capacity it was intended that yields show increasing total returns and then decreasing total returns as productive practices were improved and increased.

Comparison of the actual yield index data (Table XII) and yield index data calculated according to the formula used (Table XXIV) shows large discrepancies at similar soil quality and productive practice levels.

The difference of yield index between the soil groups for the theoretical index was much larger than the difference between soil groups of the actual data. Also the difference in yield due to productive practices within soil groups was smaller in the theoretical index than in the actual index. These small responses due to productive practices within soil groups was due to the lack of weight given the productive practices in designing the formula.

Calculation of Value of Products and Cost of Production

In order to determine the most profitable level of practices to use on the soil quality groups it is necessary to calculate the value of the crops produced on these soil groups using the various levels of practices. Also the cost of producing these crops has to be known. These costs include all costs of production such as seed bed preparation, fertilizer, labor, harvesting and hauling. Taxes and interest on investment are also included in these costs.

Calculation of Returns for Actual Yield Data

The value per acre of the crops grown on various soil quality groups was calculated. This was done by using the same percent of land for each crop as was found in the study, Table XXV. The yield used for this calculation was the actual yield of each crop in each productive practice group for each soil group, Table XII. A sample calculation of the method used is given in Table XXVI. This was calculated by finding the product of the yield index and average yield to give the yield for the crops. This yield was multiplied by the price per bushel or ton to find value per acre. This value was multiplied by the percent of the land used for this crop to give the actual value. The sum of the actual values was found which is the total value product per acre. The values of the total product for

TABLE XXV

PERCENT OF LAND IN FIVE CROPS USED TO DETERMINE TOTAL VALUE PRODUCT OF YIELDS FOR SAMPLE OF CENTRAL MICHIGAN FARMS, 1948 - 1952

	Soil Quality Class			
	0.0 - 1.0	1.1 - 2.0	2.1 - 3.0	3.1 - 4.0
Crop	Percent			
Corn	6	22	25	23
Oats	18	15	16	18
Wheat	8	6	16	13
Hay	31	27	19	24
Pasture	37	30	24	22
Total	100	100	100	100

TABLE XXVI

SAMPLE CALCULATION OF TOTAL VALUE PRODUCT PER ACRE OF LAND FOR PRODUCTIVE PRACTICE 3.5 ON SOIL QUALITY INDEX GROUP 3.5

Crop	Average yield	Yield index	Yield	Price per unit (Dollars)	Value per acre (Dollars)*	Percent of land**	Actual value (Dollars)#
Corn	51.0	112	57.1	1.50	85.65	23	16.70
Oats	45.2	115	51.9	.80	41.52	18	7.47
Wheat	30.4	110	33.4	2.00	66.80	13	8.68
Hay	2.3	101	2.3	20.00	46.00	24	11.04
Pasture	2.3	101	2.3	10.00	23.00	22	5.06
Total value per acre							48.95

*Total yield per acre times price per unit

**Actual percent of crop grown on this Soil Quality Group in this study

#Percent of land in the crop multiplied by value per acre the data taken are given in Table XXVII. No values are given for soil 0.5 or 1.5 because data for these indexes were not complete.

TABLE XXVII

ACTUAL TOTAL VALUE PRODUCTS FOR SOME POINTS OF THE SOIL QUALITY AND PRODUCTIVE PRACTICE INDEX

	Soil Quality			
	3.5	2.5	1.5	0.5
	Total Value Product Per Acre			
Productive practice	(Dollars)	(Dollars)	(Dollars)	(Dollars)
3.5	48.95	46.94		
2.5	48.19	46.90		
1.5	47.67	46.56		
0.5	40.41	31.69		

Calculation of Cost of Production of Crops

In farm planning cost of production is not only important from the standpoint of figuring returns but also is important in determining future capital requirements. Estimated production cost are given in Table XXVIII. These costs were figured only for the soil qualities and productive practice levels appearing in this Table.

TABLE XXVIII

ESTIMATED PRODUCTION COSTS* PER ACRE FOR VARIOUS POINTS OF THE SOIL QUALITY AND PRODUCTIVE PRACTICE INDEXES

	Soil Quality			
	3.5	2.5	1.5	0.5
	Production Costs			
Productive practice	(Dollars)	(Dollars)	(Dollars)	(Dollars)
3.5	48.00	42.44	36.20	30.74
2.5	42.57	36.92	30.55	24.72
1.5	36.90	30.55	24.73	18.53
0.5	31.12	24.72	18.53	12.57

*Includes plowing, fitting, planting, cultivating, harvesting and hauling, seed, fertilizer, interest on investment and taxes. Costs were determined for corn, oats, wheat, hay and pasture for the same proportion as found in the study.

Plowing. All costs involving machine operation were figured on a custom rate basis using information from Extension Folder 161.[6] Rates varied with soil type based on soil quality index. It was assumed that the cost of plowing was greater on heavy[7] soils than on light soils.

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6 Vary, Karl A., "Rates for Custom Work in Michigan", 1952 and 1953, Michigan State College Cooperative Extension Service.

7 Soils containing clay.

Fitting. This operation consists of seed bed preparation after plowing was completed. The cost of this operation was assumed to be equal for all types of soil.

Seed Cost. The seed costs were estimated for the practices indexes of 0.5 and 4.0 (Table XXIX). Costs for practices between these points were interpolated, (Figure 2). These costs were calculated using the percent of land used for each crop in each soil quality index category.

Cost for Drilling and Planting Using Different Levels of Plant Food

The differences in cost for drilling and planting as plant food is increased is one mainly of increased labor. This is shown graphically in Figure 3. The cost was estimated from Extension Bulletin 161[8] and cost increased as more plant food was added.

Combining or Picking, Hauling and Binning

These rates were taken from Extension Bulletin 161. It was assumed that the farmers' cost was increased for harvesting, hauling and binning per acre as yield increases. The increase in the rates are shown graphically in Figure 4. The rates used varied from four to five dollars for combining and one dollar to one dollar and a half for hauling and binning depending on yield.

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[8] Vary, Karl A., *op. cit.*

TABLE XXIX

ESTIMATED SEED COST FOR CORN, OATS, WHEAT AND FORAGE FOR 0.5 AND 4.0 PRODUCTIVE PRACTICE ON 3.1 - 4.0 SOIL QUALITY INDEX, 1948 - 1952

Crop	Seeding rate per acre	Seed cost per bushel	Cost per acre	Percent of land in crop*	Cost per acre**
	Productive Practice 0.5				
		(Dollars)	(Dollars)		(Dollars)
Corn	7 pounds	10.00	1.25	23	.29
Oats	2 bushels	1.00	2.00	18	.36
Wheat	1.75 bushels	3.00	5.25	13	.68
Grass	8 pounds	0.50	4.00	24	.96
Total					2.29
	Productive Practice 4.0				
Corn	9 1/3 pounds	10.00	1.67	23	.38
Oats	2 1/2 bushels	1.00	2.50	18	.45
Wheat	2 1/4 bushels	3.00	6.75	13	.88
Grass	8 pounds	0.50	4.00	24	.96
Total					2.67

*Actual percent of land in soil quality index 3.1 - 4.0.

**Calculation: Product of cost per acre and percent of land in crop.

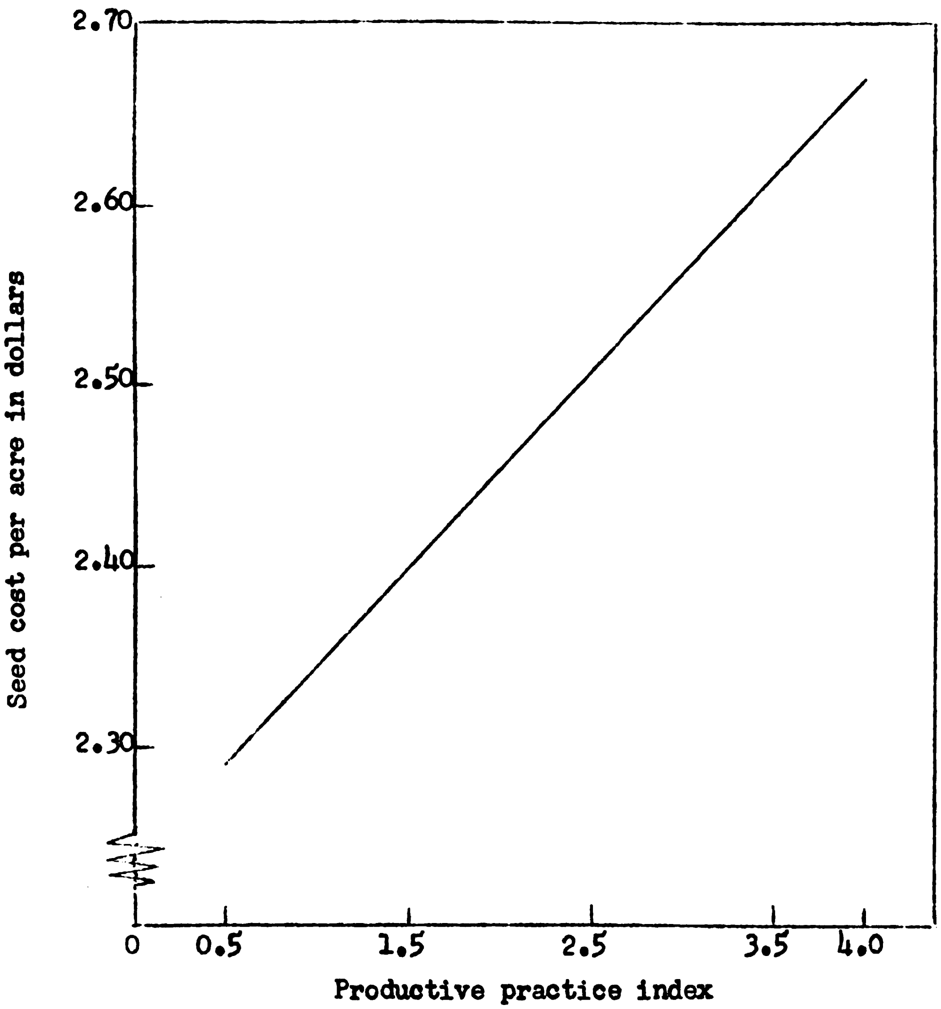

Figure 2. Estimated seed cost per acre for corn, oats, wheat, and alfalfa for levels of productive practices.

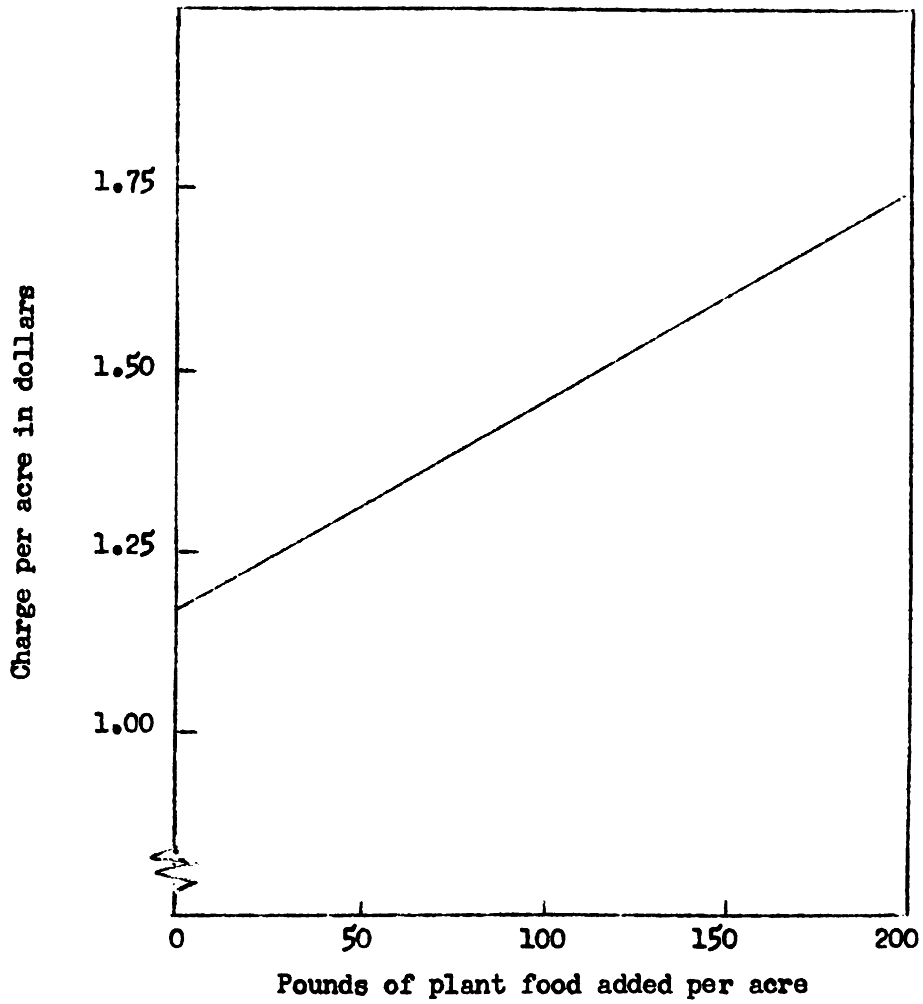

Figure 3. Estimated charge per acre for drilling grain and planting corn for rates of application of plant food.

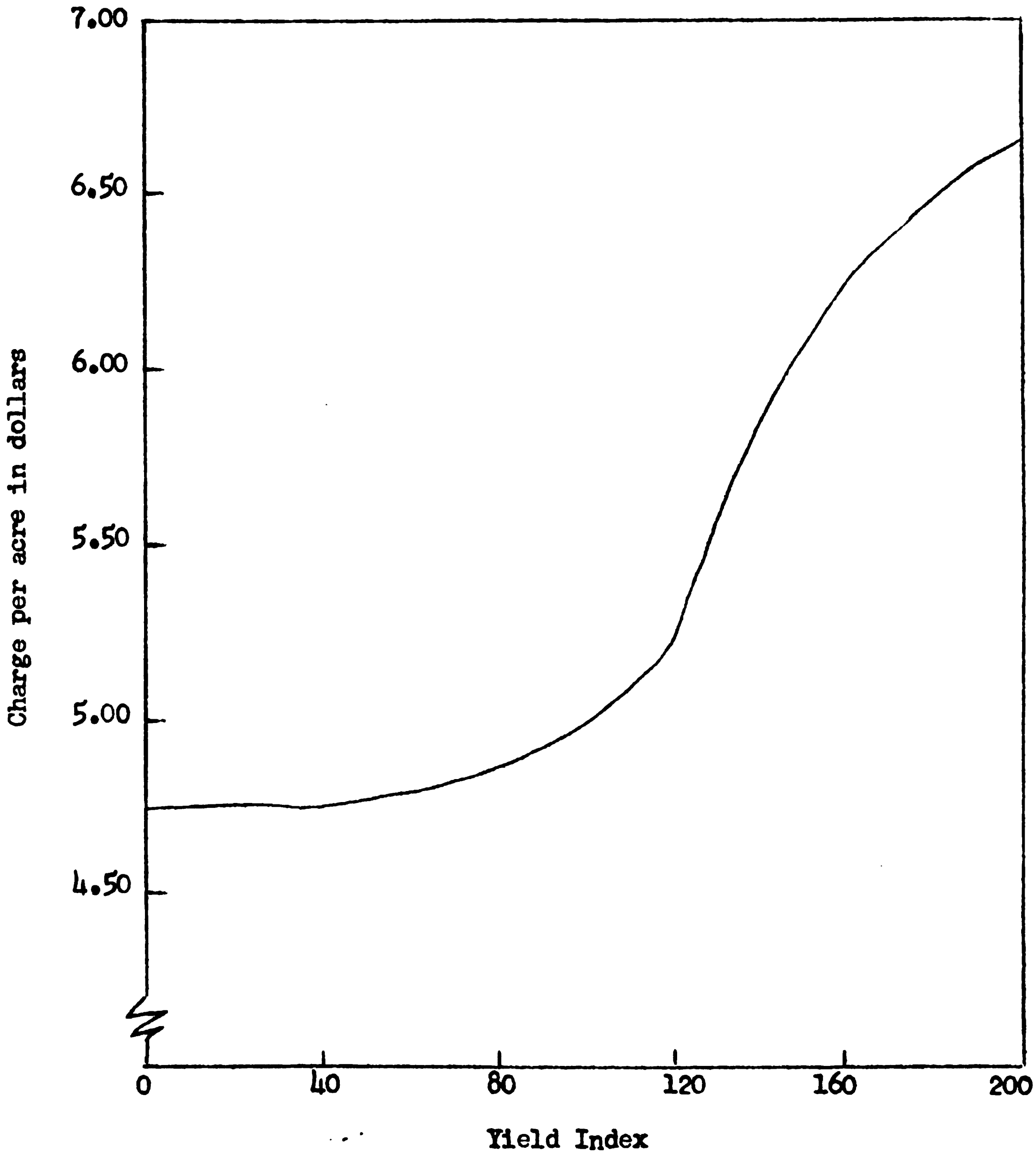

Figure 4. Estimated cost for combining or corn picking and hauling and binning per acre for various yield indexes.

Interest on Investment and Taxes

Interest on investment was calculated on normal estimated value of land capitalized at five percent per year, Figure 5. Taxes were calculated on estimated assessed value at the rate of fifteen mills per dollar of value, Figure 5. The values used for assessed value are given in Table XXX.

TABLE XXX

HYPOTHETICAL ASSESSED VALUE OF LAND FOR VARIOUS SOIL QUALITIES FOR CENTRAL MICHIGAN FARMS

Soil Quality	Assessed Value (Dollars)	Taxes (Dollars)
0.5	62	0.93
1.5	88	1.32
2.5	112	1.68
3.5	138	2.07

The entire cost of production is given in a sample calculation, (Table XXXI).

Equating of Marginal Cost and Marginal Value Product

In order to determine the level of practices that should be used on 3.5 soil quality, Table XXVII has to be used. It is found that the marginal value products for this soil quality between productive practice levels from low level practices to high level were

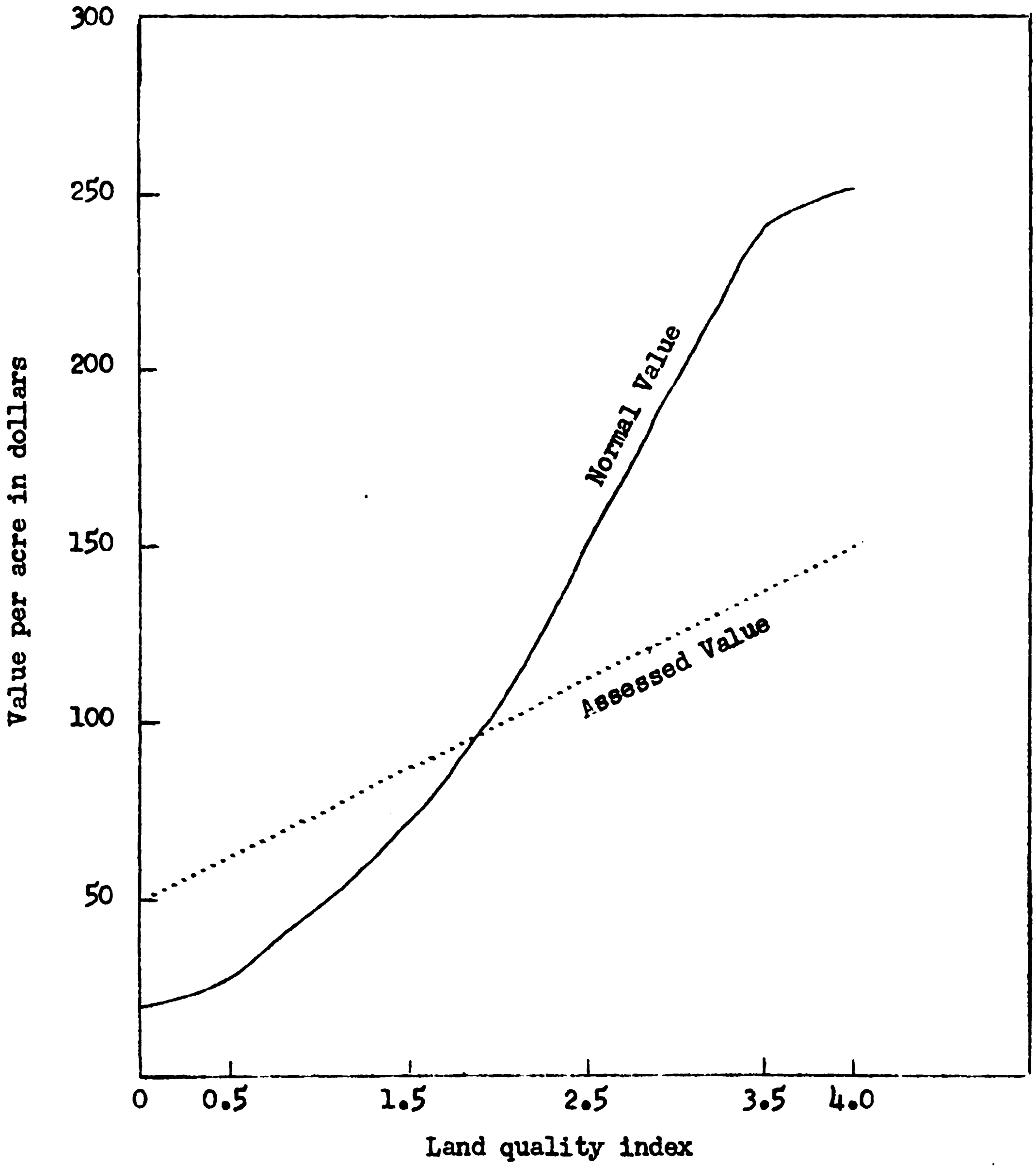

Figure 5. Estimated land value, normal and assessed for determining interest on investment at five percent and taxes figured at fifteen mills per dollar.

TABLE XXXI

SAMPLE CALCULATION OF ESTIMATED PRODUCTION COST PER ACRE OF LAND, SOIL QUALITY INDEX 3.5 AND PRODUCTIVE PRACTICE INDEX 0.5

	Number of operations	Percent of land covered*	Cost per acre**	Actual cost#
			(Dollars)	(Dollars)
Plow	1	54	4.00	2.16
Fit	3	54	4.50	2.43
Drill and plant	1	54	1.25	.67
Cultivate	3	23	3.75	.86
Combine or pick and haul	1	54	5.28	2.61
Bale and haul##	1	24	14.70	3.53
Fertilizer, ten cents per pound plant food	1	100		2.50
Seed				2.29
Interest on land investment				12.00
Taxes on land				2.07
Total cost				31.12

*Fifty-four percent of the land has to be plowed. This is the total of land used for corn, oats and wheat.

**From Extension Folder 161, "Rates for Custom Work in Michigan", 1952 and 1953, by Karl A. Vary, Michigan State College Cooperative Extension Service.

#Percent of land multiplied by cost per acre.

##Fifteen cents per bale, 35 bales per ton.

seven dollars and twenty-six cents, fifty-two cents and seventy-six cents, Figure 6. Using the same points from Table XXVIII which is cost of production, the marginal costs were approximately six dollars. The equating of marginal cost and marginal value product is approximated at productive practice level 1.2. A more accurate approximation of this point could be made by using smaller increments of productive practices.

For soil quality 2.5 the marginal value products (Table XXVII) between levels of practices from low practices to high practices were fourteen dollars and seventy-eight cents, thirty-four cents and four cents. These are shown graphically in Figure 7. From this figure it can be seen that marginal cost and marginal value product is approximately equated at practice level 1.6.

Relevancy of Equating Marginal Cost and Marginal Value Products

For soil index 3.5 the marginal cost and marginal value product is equated approximately at productive practice level 1.2. The plant food added per acre per year at this level is sixty pounds. For a rotation of corn, oats, wheat, hay and pasture the analyses and amounts of fertilizer recommended by the Department of Soil Science are given in Table XXXII. The total amount of plant food recommended for the rotation is 302 pounds or an average of 60.4 pounds of plant food per acre per year. These recommendations are for soils of high productive capacity

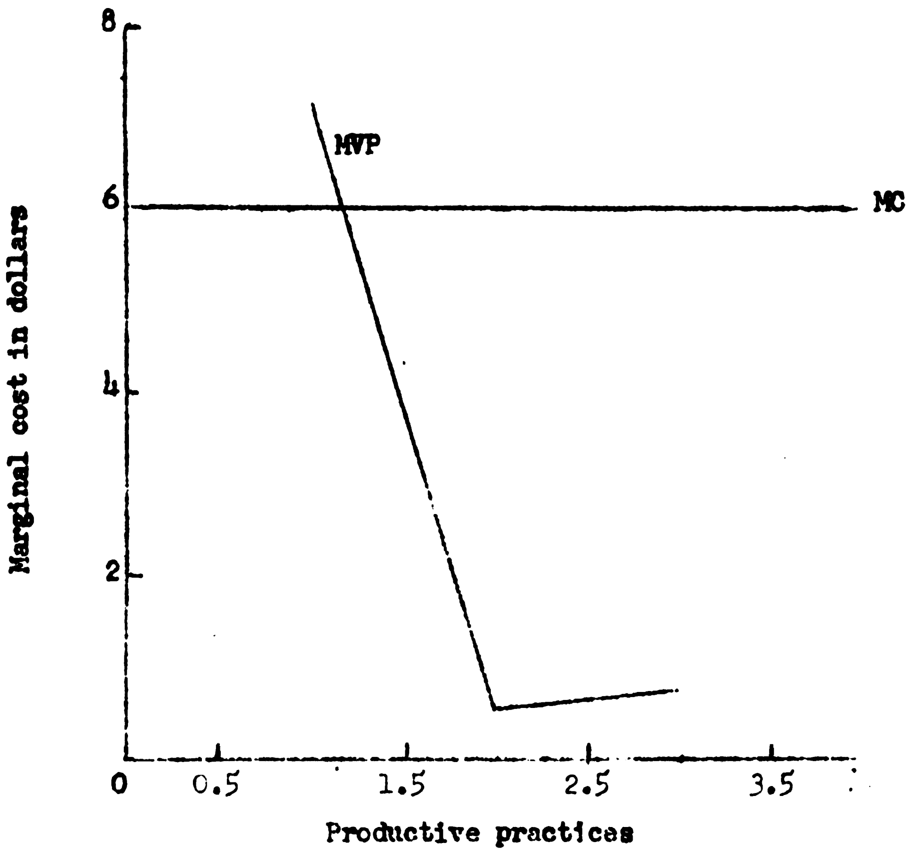

Figure 6. Marginal cost and marginal value product for soil quality index 3.5 for some levels of productive practices using actual yield data and estimated production cost.

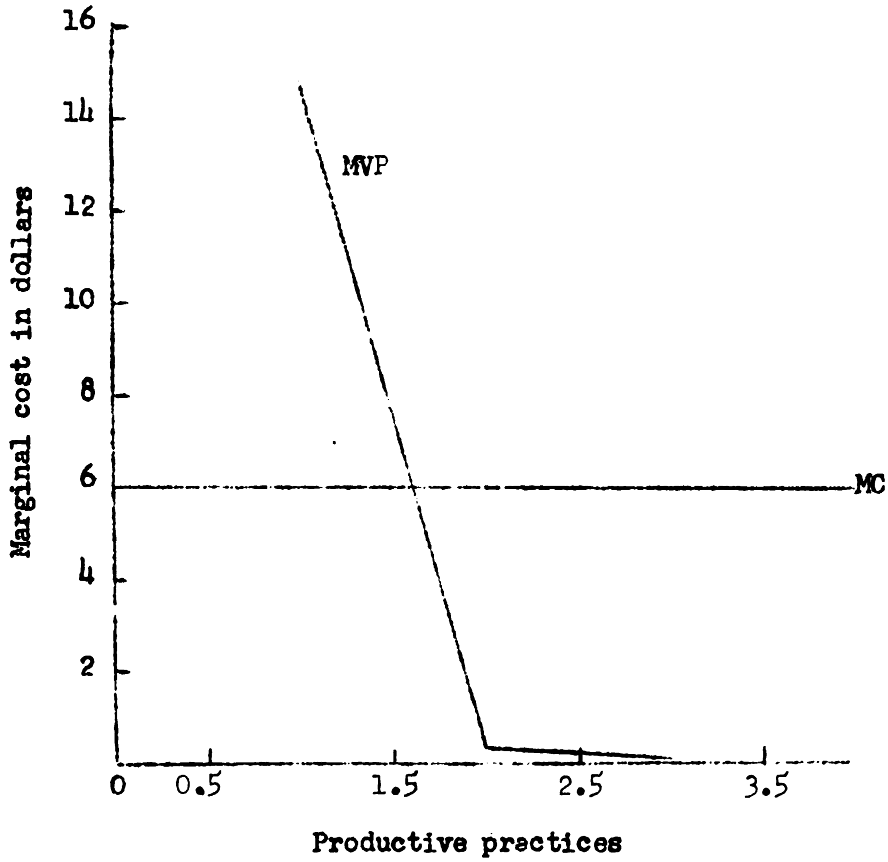

Figure 7. Marginal cost and marginal value product for soil index 2.5 for some levels of productive practices using actual yield data and estimated production cost.

TABLE XXXII

CROPS OF A ROTATION AND RECOMMENDED AMOUNTS AND ANALYSIS OF FERTILIZER FOR BROOKSTON, AND SIMILAR SOIL SERIES*

Rotation	Pounds of fertilizer per acre	Analysis of fertilizer	Pounds of plant food per acre
Corn	160	0-20-0	32
Oats	300	4-16-4	84
Wheat	450	4-16-4	126
Alfalfa			
Alfalfa	300	0-20-0	60
Total plant food			302

*Extension Bulletin 159, "Fertilizer Recommendations for Michigan Crops", Department of Soil Science and Horticulture, Michigan State College Cooperative Extension Service, East Lansing, Michigan, p. 11. Recommendations for phosphorus low, potassium high.

similar to soil quality index 3.5 when phosphorus is low and potassium is high. The total amount of plant food recommended for the rotation is 302 pounds or an average of 60.4 pounds of plant food per acre per year. When phosphorus is high and potassium is low 240 pounds of plant food is recommended for this rotation. This is an average of 48 pounds of plant food per acre per year.

For soil index 2.5 the marginal cost and marginal value product was equated at productive practice level of 1.6. At this level, plant food is being added at the rate of 80 pounds of plant food per acre per year.

Table XXXIII gives the recommended amounts and analysis for a rotation when phosphorus is low and potassium is high for Hillsdale, Fox and similar soil series. These soils were given an index rating of 2.5 in this study.

TABLE XXXIII

CROPS OF A ROTATION AND RECOMMENDED AMOUNTS AND ANALYSIS OF FERTILIZER FOR HILLSDALE, FOX AND SIMILAR SOIL SERIES*

Rotation	Pounds of fertilizer per acre	Analysis of fertilizer	Pounds of plant food per acre
Corn	150	4-16-8	42
Oats	225	4-16-8	63
Wheat	450	4-16-8	126
Alfalfa	200	0-20-10	60
Alfalfa	300	0-20-10	90
Total plant food			381

*Extension Bulletin 159, "Fertilizer Recommendations for Michigan Crops", Department of Soil Science and Horticulture, Michigan State College Cooperative Extension Service, East Lansing, Michigan, p. 13. Phosphorus low, potassium high.

The amount and analysis of fertilizer recommended adds up to a total of 381 pounds of plant food for the entire rotation. This is an average of 76 pounds to be added per acre per year. The recommded analyses and amount for phosphorus high and potassium low is 74 pounds per acre per year for this rotation.

The Average Farmers Use of Fertilizer

Area five farm account cooperators use on the average about three dollars and seventy-five cents worth of fertilizer per tillable acre per year.[9] Using seventy dollars per ton as the price of fertilizer, this three dollars and seventy-five cents indicates that the average amount of fertilizer used by Area five farmers is 107 pounds. If the average analysis of this fertilizer is 3-18-9, the average amount of plant food used from fertilizer is about 32 pounds per tillable acre per year. From this figure it is evident that farmers could use more plant food profitably unless the deficit is made up by using large amounts of manure.

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9 "Farm Business Analysis", Area 5, Dairy and General Farming, Michigan State College Cooperative Extension Service, Agricultural Economics Department, April, 1953.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Review of Soil Quality Index

The need for the three factors used in the land quality index should be reviewed. The results of the statistical treatment show that there is significance between yield in more cases between soil type groups than between soil quality index groups. This fact may substantiate the theory that only soil type need be used for an index. However, in cases where drainage is a limiting factor to production this will not give an accurate description of productive capacity of the soil. Likewise when slope is a limiting factor of productive capacity and it is omitted the description is not an accurate one.

Review of Productive Practices Index

The three factors (plant food added, humus maintenance and pH) used in computing the productive practice index were weighted equally. It is not known if this is the correct weighting or if the plant food should be weighted heavier than the other two factors, or if humus maintenance and pH level should be weighted equally, or if plant food alone should be used.

Variation of Yield Between Levels of Productive Practices on Similar Soil Quality

Improved practices were accompanied by a decrease in crop yield variation in nearly all cases. It was found that variation in crop yields were greater for all crops grown on soil quality 3.1 - 4.0 when practices in the range 0.0 - 2.0 were used in comparison to practices 2.1 - 4.0. Also the variation for average of all crops was greater for the lower level of practices. Significant differences in yield between these two practice groups on this soil were found for wheat, oats and average of all crops.

For soil quality group 2.1 - 3.0, greater variation for the lower level practices was found for oats, corn, alfalfa and average of all crops. Significant yield differences were found in this soil group between the two levels of practices for alfalfa and average of all crops.

Variation in Yield Between Different Soil Quality Groups Disregarding Levels of Productive Practices

There tends to be less variation in crop yields on good soil than on soil of lower quality. This was found to be true if soil quality index was used or soil type alone was used.

Variation of yield was found to be greater for soil quality group 2.1 - 3.0 for corn, alfalfa and average of all crops when a comparison was made with variation of yield for soil quality group 3.1 - 4.0. Significant differences in yields were found for corn and average of all crops between soil quality groups 3.1 - 4.0 and 2.1 - 3.0. Significant differences in yields were also found for oats, alfalfa and average of all crops between soil quality groups 2.1 - 3.0 and 1.1 - 2.0.

Variation of Yield for Different Soil Type Groups Disregarding Level of Practices

Larger differences in yields were generally found between soil type groups than was found between soil quality index groups. The yield variation of wheat, corn and average of all crops was greater in soil type group 2.1 - 3.0 than 3.1 - 4.0. Variation of yield was greater for all crops except wheat in the 1.1 - 2.0 soil type group than it was in 2.1 - 3.0.

Significant differences in yield were found for all crops except alfalfa between soil type group 3.1 - 4.0 and 2.1 - 3.0. A significant difference was found for average of all crop between soil type 1.1 - 2.0 and 2.1 - 3.0. A significant difference in yield was found for alfalfa and average of all crops between soil type groups 0.0 - 1.0 and 1.1 - 2.0.

Comparison of Variation of Yield for Individual Crops

Results shows a tendency for less yield uncertainty for some crops than for others. Under conditions of similar practices on similar soil quality, oats and corn yields were found to vary more than wheat and alfalfa yields.

It was found that variation in yield for wheat was generally the smallest over all the soil type groups.

One of the reasons for wheat and alfalfa having a smaller yield variation than corn and oats was that alfalfa and wheat had the advantage of using moisture from snow and very early spring rains. Corn and oats are not planted early enough to take advantage of this moisture. This advantage was greater on the sand, sandy loam and loamy sand soil classes than on soils of heavier texture due to more rapid internal drainage for the sandy soils.

Equating of Marginal Cost and Marginal Value Product

It was found that on soil quality 3.5 marginal cost and marginal value product were equal at productive practice level 1.2. At this level of productive practices 60 pounds of plant food per acre per year is added. For soil quality 2.5, marginal cost and marginal value product was equated at productive practice level 1.6. At this level 80 pounds of plant food per acre per year is added.

Farmers can make good use of the information contained in this study if they know the soil types on their farm. The productive practices they use should be familiar to them and the index of productive practices is quite simple and easy to calculate.

With these basic data and the information given here he can predict his yield more accurately than he could using average yields of crop reporting districts or state averages.

The information in the study will also give him an estimate of returns and cost of production over the range of practices he may want to use.

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