THE INFLUENCE OF CONTRASTING ADJACENT SOIL REGIONS ON THE AGRICULTURAL SYSTEMS OF SELECTED AREAS IN ILLINOIS, INDIANA, AND OHIO

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ABSTRACT

THE INFLUENCE OF CONTRASTING ADJACENT SOIL REGIONS ON THE AGRICULTURAL SYSTEMS OF SELECTED AREAS IN ILLINOIS, INDIANA, AND OHIO

by
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Contrasting adjacent soil regions were used in this study as a framework to examine agricultural systems, to demonstrate the influence of soils on these systems, and to show that soil is a primary agent in effecting differences in agricultural systems in general. The farming types which characterized each agricultural system were examined in detail to determine the extent and degree of contrast between the adjacent soil regions. The group of factors analyzed included: farm size, allocation of land use on the farm, types of crops, crop yields, crop rotations, fertilizer application rates, and land values.

The study was located in three separate areas of the Central Lowlands of the United States. One area was in east central Illinois, the second in southeast Indiana, and the third in southwest Ohio. Each area had a northern region of Wisconsin age till plain soils and a southern region of Illinoian age till plain soils. A Wisconsin age terminal moraine marked the boundary between soil regions in each area.

A group of twenty-five farms was selected at random in each of the soil regions chosen for this study. Data on the production aspects of each farm were gathered from records in the Agricultural Stabilization and Conservation Service office in each county and from direct interview of individual farm operators.

Most of the data gathered in the field was analyzed using a one-way analysis of variance test. The rest of the data, pertaining to the presence or absence of a factor, was analyzed using the Chi-square test. All tests were conducted at a .01 significance level. The results of the analyses indicated that six factors displayed significant differences between soil regions in all three study areas. These factors were: the Storie Index (soil productivity), value of land per acre, percentage of farm in cropland, percentage of farm in woodlot, percentage of cropland in corn, and type of artificial drainage. Five other factors--corn yield, phosphorus fertilizer application rate on soybeans, potassium fertilizer application rate on soybeans, total fertilizer application rate on soybeans, and percentage of cropland in soybeans--showed a significant difference between soil regions in two of the study areas and approached the .01 level of significance in the third study area.

The results of analysis of data classified each of the three Illinoian age soil regions as a mixed farming type region. The Wisconsin age soil regions in Ohio and Indiana were classified as corn-livestock farming type regions. The Wisconsin age soil region in Illinois was classified as a cash grain farming type region. Thus, the adjacent soil regions in each study area were classified as different farming types based on the soil differences.

The number of significant variables for each study area in this thesis did not appear to be the result of other factors than the contrasting soils. Thus, the initial hypothesis that contrasting adjacent soil regions influenced differences in agricultural systems of these regions was accepted. It was felt that this study reiterated the value of using soil data to verify the existence of contrasting physical regions, provided a better insight into the role of soils in influencing differences in agricultural systems, indicated the factors within the agricultural systems which could vary significantly with differences in soils, and indicated the need for further studies of a similar nature in other areas to demonstrate the role of soils in influencing land use patterns and agricultural systems.

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Arthur G. Limbird

A THESIS

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DEDICATION

This dissertation is dedicated to the memory of my brother,

William S. Limbird, Jr.

(11/3/40 - 8/22/71)

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Most of all, a special thanks to my wife, Kay, who both typed this dissertation and offered strength and understanding throughout my five years of graduate school.

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

Part 1. Agricultural Systems and the Physical Environment

Agricultural geography is one branch of human geography which concerns itself directly with both cultural and physical phenomena. It concerns itself more with the physical environment than any other segment of cultural geography.[1] Agricultural patterns are in fact good examples of spatial distributions that are influenced both by man and by the physical environment. The distribution of agriculture throughout the world lends itself to explanation partially by limits imposed by the environment and partially by human choices.[2] As expected, many research studies have discussed agricultural patterns in terms of man's influence, while a number of others have discussed such patterns in terms of the influence of physical factors.[3]

There is strong agreement among geographers that the primary objective of agricultural geography is the

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1. Howard F. Gregor, Geography of Agriculture: Themes in Research, Prentice-Hall, Englewood Cliffs, New Jersey, 1970, p. 31.
2. Maurice H. Yeates, An Introduction to Quantitative Analysis in Economic Geography, McGraw-Hill Book Company, New York, 1968, p. 47.
3. See Gregor, op. cit., for several examples.

study of the areal variation of agriculture, no matter which mode of explanation is used. The agricultural geographer endeavors to understand the spatial differences in agriculture and the reasons for these differences. Often the areal variations of agriculture are discussed within a regional context as in the work of Baker,[4] Weaver,[5] and Coppock.[6] It remains true that different areas of the world possess agricultural characteristics which clearly distinguish one area from another. Agricultural geography attempts to define these areas of variation. The concept of the region thus is considered to be of fundamental importance in studies of agricultural geography.

The majority of regional studies in agricultural geography have been restricted to a single region or to the regional pattern of single features. More recently, there has been an increasing interest in more complex regional phenomena such as farming types.[7] Regional comparisons have been introduced in order to understand more fully the similarities and differences

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4. O.E. Baker, "Agricultural Regions of North America," Economic Geography, vol. 2 (1926), pp. 459-493.

5. J.C. Weaver, "Crop-Combination Regions in the Middle West," Geographical Review, vol. 44 (1954), pp. 175-200 and 560-572.

6. J.T. Coppock, "Crop, Livestock, and Enterprise Combinations in England and Wales," Economic Geography, vol. 40 (1964) pp. 65-81.

7. Gregor, op. cit., p. 112.

of two regions. The regions compared are usually similar ones, such as in the articles of Meinig[8] and Lewthwaite,[9] because the common characteristics were the attracting forces for the researchers. There thus appears to be a need to examine farming types or agricultural systems on a comparative basis between dissimilar regions.

The agricultural region can be viewed as being as large or as small as the particular study demands. From the individual standpoint, the farmer, influenced by physical and cultural factors, makes decisions on adopting various forms of work and production into a farming type. These decisions by several farmers help to create a combination of similar characteristics which integrates the farming type into an agricultural system of a region. The areal extent of the region may or may not correspond with physical regions or with political units. Thus, the identification and description of farming types and agricultural systems along with the areas they occupy have long been a major

8. D.W. Meinig, "Colonization of Wheatlands: Some Australian and American Comparisons," Australian Geographer, vol. 7 (1959) pp. 205-213.

9. G.R. Lewthwaite, "Wisconsin and the Waikato: A Comparison of Dairy Farming in the United States and New Zealand," Annals of the Association of American Geographers, vol. 54 (1964) pp. 59-87.

concern to agricultural geographers.[10] When discussing the variations of agricultural systems within a restricted location, the examination of individual farms to determine how they fit into the context of the farming type--agricultural system--agricultural region hierarchy seems desirable.

Gregor[11] observes that conditions in the United States have favored a close adjustment of agriculture to differences in the physical environment. A number of physical environments are found in a subcontinental framework; a well developed transportation system exists in the country; the economy is dominantly commercial; agricultural technology is more advanced than in many other areas; and most importantly, rural populations are strongly rationalistic in their attitudes toward the land. These assumptions in whole or in part have pervaded past studies in agricultural geography in the United States as related to the physical environment.

Approaches to the question of the relationship between agriculture and the physical environment have been varied and changing over the past half century in agricultural geography. Early in this period it was

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10. Leslie Symons, Agricultural Geography, Frederick A. Praeger, Inc., New York, 1967, p. 95.
11. Gregor, op. cit., pp. 42-43.

realized that commercial agriculture is a highly competitive industry making crop and livestock production sensitive to even small physical advantages or disadvantages of a particular region. Physical factors can in large degree influence the utilization of land within an area. Baker[12] discussed the increased tendency for the patterning of land use in close relation to variations in topography, soils, temperature, and moisture. He stressed that an area characterized by homogenous agricultural conditions--especially in the type of crops grown--was mainly determined by climate. Subdivisions of these regions were due to differences in slope and in soils which could influence variability in the proportion of land used for crops or the relative importance of the crops.[13]

Intensive study of the increasingly closer adjustment of agriculture to areas with the best physical environment revealed that agriculture is more extensive on poorer lands and more intensive on better lands.[14] The best land for agricultural production is that which is the most fertile and easily cultivated and which shows higher yields than less fertile land. These pro-

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12. O.E. Baker, "The Increasing Importance of the Physical Conditions in Determining the Utilization of Land for Agriculture and Forest Production in the United States," Annals of the Association of American Geographers, vol. 11 (1921) pp. 17-46.

13. O.E. Baker, "Agricultural Regions of North America," Economic Geography, vol. 2 (1926) pp. 459-493.

14. Gregor, op. cit., p. 42.

ductive areas tend to attract labor and capital more readily than do less productive areas. Physical factors, then, may be important in influencing differences in agricultural systems within agricultural regions.

In attempts to discern the spatial patterns of these so-called "better lands" a number of research studies have separated the physical environment into its component parts. Several earlier studies, such as those of Rose,[15] Weaver,[16] and Vischer,[17] stressed the effects of climate on agriculture. Other studies dealing with climates examined those climatic locations suitable for various crops.[18] Work by geographers in analyzing the influence of topography in agriculture has had a long period of development. Plains in particular have received abundant attention because of their close relationship to agricultural activity.[19] Studies have included the entire terrain of an area or dealt with single landforms.

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15. J.K. Rose, "Corn Yield and Climate in the Corn Belt," Geographical Review, vol. 26 (1936) pp. 88-101.

16. J.C. Weaver, "Climatic Relations of American Barley Production," Geographical Review, vol. 33 (1943) pp. 588-596.

17. S.S. Visher, "Weather Influences on Crop Yields," Economic Geography, vol. 16 (1940) pp. 436-443.

18. C.W. Thornthwaite, "An Approach Toward a Rational Classification of Climate," Geographical Review, vol. 38 (1948) pp. 55-94.

19. J.J. Hidore, "Relationship Between Cash Grain Farming and Landforms," Economic Geography, vol. 39 (1963) pp 84-89.

Research on the influence of soil on agricultural patterns has been less intensive than the influence of climate and topography. Some geographers have been concerned with optimum soil areas for individual crops. A few others have combined soils and climate to discern the most productive soil for a crop. One way of studying the effect of man on soil productive capacity is to concentrate on specific soil regions. Wolfanger carried out such studies in the 1920s and 1930s.[20, 21] Since that time, few geographers have been willing to give priority to soils. They prefer to consider them as a secondary element in agricultural processes.[22]

Soil scientists and crop scientists have done much research which the geographer can draw upon and place in a spatial framework. They have demonstrated that differences in the degree of soil weathering and soil development can result in many important variations in soils. These variations can strongly influence production and management practices on farms, such as artificial drainage, fertilizer applications, and cropping systems.[23] Soil development depends on climatic forces

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20. L.A. Wolfanger, "Economic Geography of the Gray-Brownerths of the Eastern United States," Geographical Review, vol. 21 (1931) p. 277.

21. L.A. Wolfanger, "Abandoned Land in a Region of Land Abandonment," Economic Geography, vol. 7 (1931) pp. 166-176.

22. Gregor, op. cit., p. 37.

23. B.W. Ray, "Degree of Weathering and Development Affects Soil Properties and Management Practices," Agronomy Facts, University of Illinois, SP-4, 1955.

acting on parent materials under the influence of vegetation and landforms over varying lengths of time.[24] These five factors of soil formation--climate, vegetation, topography, parent material, and time--can result in different soil types which in turn may reflect contrasting agricultural systems.

Differences in soils can be local or regional in nature. Each soil type occurs in a definite geographic area and in certain spatial patterns with other soil types. Neighboring soils may have large or small differences which may have an important bearing on their use or management. A large number of soils within a small area often have many features in common. Thus, regional differences are normally larger and are usually related to climate or vegetation. However, in places, important differences reflect variation in topography, ages of land surfaces, or the character of the parent material.[25] Wolfanger[26] found that such was the case in the Chesapeake Bay Region. He studied an area of contrasting soils; one old, infertile, and aged by nature on a level surface and the other younger, more

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24. T.M. Bushnell, A Story of Hoosier Soils, Peda-Products, West Lafayette, Indiana, 1958, p. 11.

25. Roy W. Simonson, "What Soils Are," Soil, the Yearbook of Agriculture, 1957, USDA, Washington, D.C., pp. 17-31.

26. L.A. Wolfanger, "Abandoned Land in a Region of Land Abandonment," Economic Geography, vol. 7 (1931) pp. 166-176.

fertile, and more physically capable of crop production. Yields were low, potential was low, and the farms often abandoned on the old soil. The production capability was good, yields were relatively high, and few farms were abandoned on the younger soil.

The principle of intensification of production on better soils seems to lend itself to a regional geographic approach to contrasts between natural fertility and soil productivity. The spatial context of such research is clearly within the realm of agricultural geography. However, there has been comparatively little recent work done by geographers on the interaction between soils and agricultural patterns. There exists an apparent need for more detailed work on the relationships between soils and agricultural systems in a spatial framework. Further, there is a need to examine agricultural systems by comparing them in dissimilar regions.

Part 2. An Approach to the Interaction of Soils and Agricultural Systems

Statement of the Problem

Although it is recognized that a relationship can exist between soils and agricultural systems within a region, little geographical research has been carried out on the extent and magnitude of this relationship.

The use of contrasting soil regions as a framework to examine agricultural systems may demonstrate the influence of soils on these systems and show that soil is a primary agent in effecting differences in agricultural systems in general. It is hypothesized that contrasting soil regions located adjacent to one another result in differences in the agricultural systems occuring between these regions. In order to investigate the validity of this statement, three concise, separate areas of the midwest are included in the study. Each area has contrasting adjacent soil regions and presumably, contrasting agricultural systems. Thus, the influence of soil variations on these systems is examined within limited and well defined areas.

As the purpose of this study is to determine the effect of contrasting adjacent soil regions in each of the three chosen study areas on the agricultural system in each region, the systems must be broken down into their component parts. The farming types which characterize each system need to be examined factor by factor to determine the extent and degree of contrast between the adjacent soil regions. The group of factors includes farm size, allocation of land use on the farm, types of crops, yields, crop rotations, fertilizer application rates, farm labor, and land value.

In this thesis the farming types in each region of the study area are investigated. A sample group of individual farms in each region forms the framework of analyzing those agricultural factors which comprise the farming type and thus influence the agricultural system. Each sample group is used to determine which of the non-physical agricultural factors contrast in each of the study areas. While the actual data may vary among the three study areas, these factors can be useful measures of the degree of contrast in each area. Therefore, in investigating the relationship between the contrasting soil regions and the agricultural systems, a basic secondary hypothesis is examined. It is theorized that similar non-physical agricultural factors contrast in each of the three study areas, indicating that a similar degree of contrast exists in each area.

Study Areas: East-Central Illinois, Southeast Indiana, and Southwest Ohio

The study is located in three separate areas of the Central Lowlands Province of the United States. One area is in east central Illinois, the second in southeast Indiana, and the third in southwest Ohio (see Figure 1.) These three particular areas of the midwest are chosen for analysis because of the apparent contrasting adjacent soils found in each of them. This study is restricted to three portions of the area which

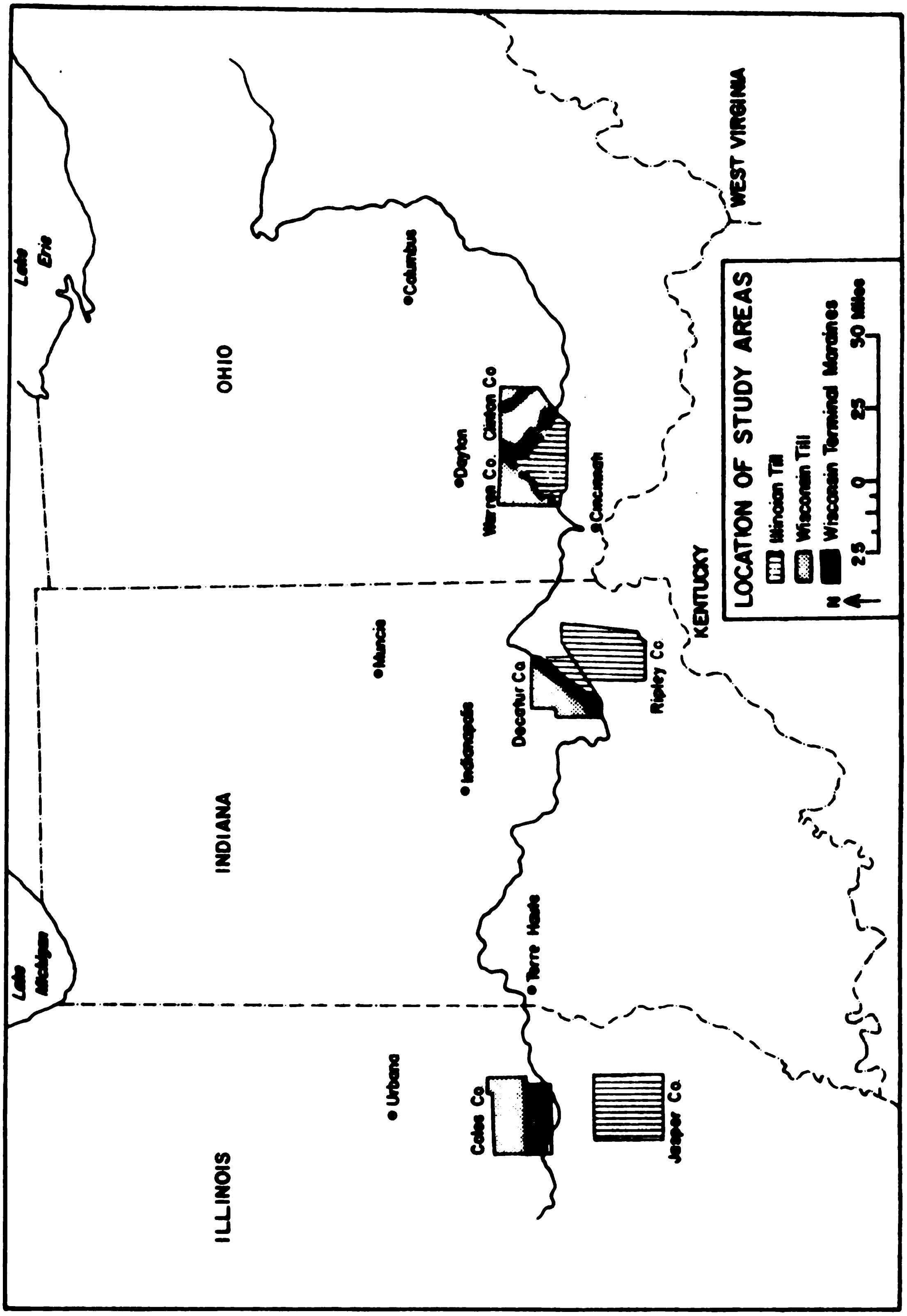

Figure 1. LOCATION OF STUDY AREAS. (Source: Glacial Map of the United States East of the Rocky Mountains, Geological Society of America, 1959.)

possibly could be studied and to sample groups of farms within each portion in order to more intensively investigate the relationships under examination.

Each of the three study areas has a southern region which was covered by the Illinoian age ice sheet and is part of the nearly level till plain of that age. The soils of these southern regions are "planosolic" Alfisols,[27] which developed on gentle slopes where surface drainage has been deficient and internal drainage slow. The subsoil is characterized by a relatively impermeable claypan or fragipan horizon.[28] In Illinois, the "planosolic" soil region is extensive, covering all or part of twenty-nine counties in the southern part of the state. Jasper County has been selected to represent this "planosolic" soil region. In Indiana, the "planosolic" soils are scattered over parts of five counties. The "planosolic" soils of Decatur County and Ripley County have been selected to represent this soil region. In Ohio, the "planosolic" soils cover scattered parts of five counties. The "planosolic" soils of Warren County and Clinton County have been selected to represent this region. Each of the three

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27. "planosolic" Alfisol is a term used in this study to indicate an Alfisol of the 7th Approximation soil classification which has the claypan or fragipan characteristic of the planosol of older soil classifications.

28. University of Wisconsin, Soils of the North Central Region of the United States, Agricultural Experiment Station Bulletin 544, 1960, pp. 36-37.

sample regions has been selected because of nearness to an adjacent contrasting soil region and because of available soil survey data.

Each of the three study areas has a northern region which was covered by the Wisconsin age ice sheet at a much more recent time than the Illinoian ice sheet covered the southern region. The northern regions are parts of the nearly level to gently rolling till plains of Wisconsin age. The soils of these northern regions are imperfectly to poorly drained Alfisols and Mollisols developed on gentle slopes where surface drainage has been deficient and internal drainage moderate.[29] The claypan or fragipan horizon characteristic of the Illinoian age soils is absent in these Alfisols and Mollisols. In all three study areas, the Wisconsin age till plains cover relatively extensive areas. Each northern region has been selected to represent the larger till plain area on the basis of its nearness to the adjacent contrasting region to the south, on the availability of soil survey data, and on the physical similarities between the adjacent regions which are controlled to be constant factors in this study--till plain landform, slight topographic relief, slopes less than five percent, and silt loam or silty clay loam

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29. Ibid.

surface soil texture. In Illinois, the till plain Mollisols of Coles County have been selected to represent the Wisconsin age till plain area. In Indiana, the till plain Alfisols and Mollisols of Decatur County have been chosen to represent the till plain of this area. In Ohio, the till plain Alfisols and Mollisols of Warren County and Clinton County have been selected.

As defined in this thesis, the study is composed of three areas, one each in Illinois, Indiana, and Ohio. Each area is composed of two regions, one of Illinoian age soils and the other of Wisconsin age soils. Each region is restricted in size to the soil associations under consideration in this study within the boundaries of the counties selected. Thus, the study areas are limited in their areal extent and their boundaries are well-demarcated to facilitate the investigation process (see Figures 2,3, and 4.)

Methods and Anticipated Results

The hypotheses of this study were tested using a research plan in which the first step was the verification of the existence of the adjacent contrasting soil regions. Once this existence was established, the next step was the study of a number of factors associated with agricultural systems generally found in the section of the midwest chosen for the study location to determine the degree of contrast each individual factor

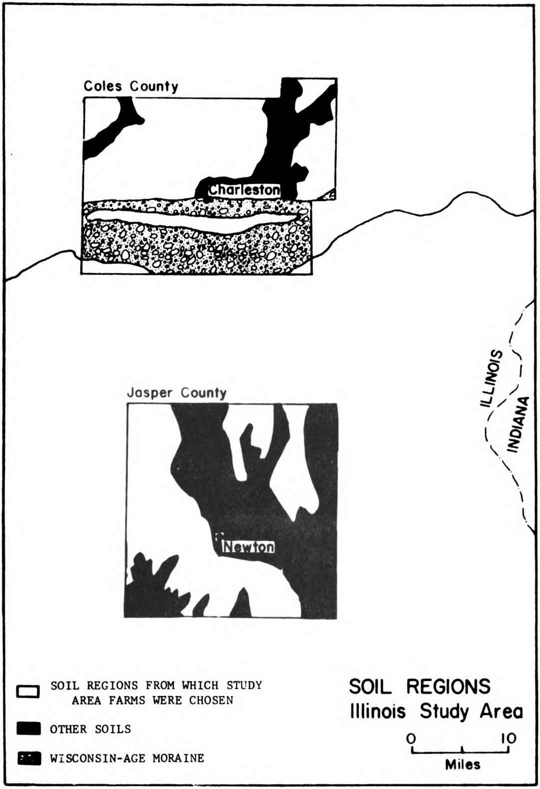

Figure 2. SOIL REGIONS Illinois Study Area. (Source: Fehrenbacher, Walker, and Wascher, Soils of Illinois, University of Illinois Agricultural Experiment Station, Bulletin 725, 1967.)

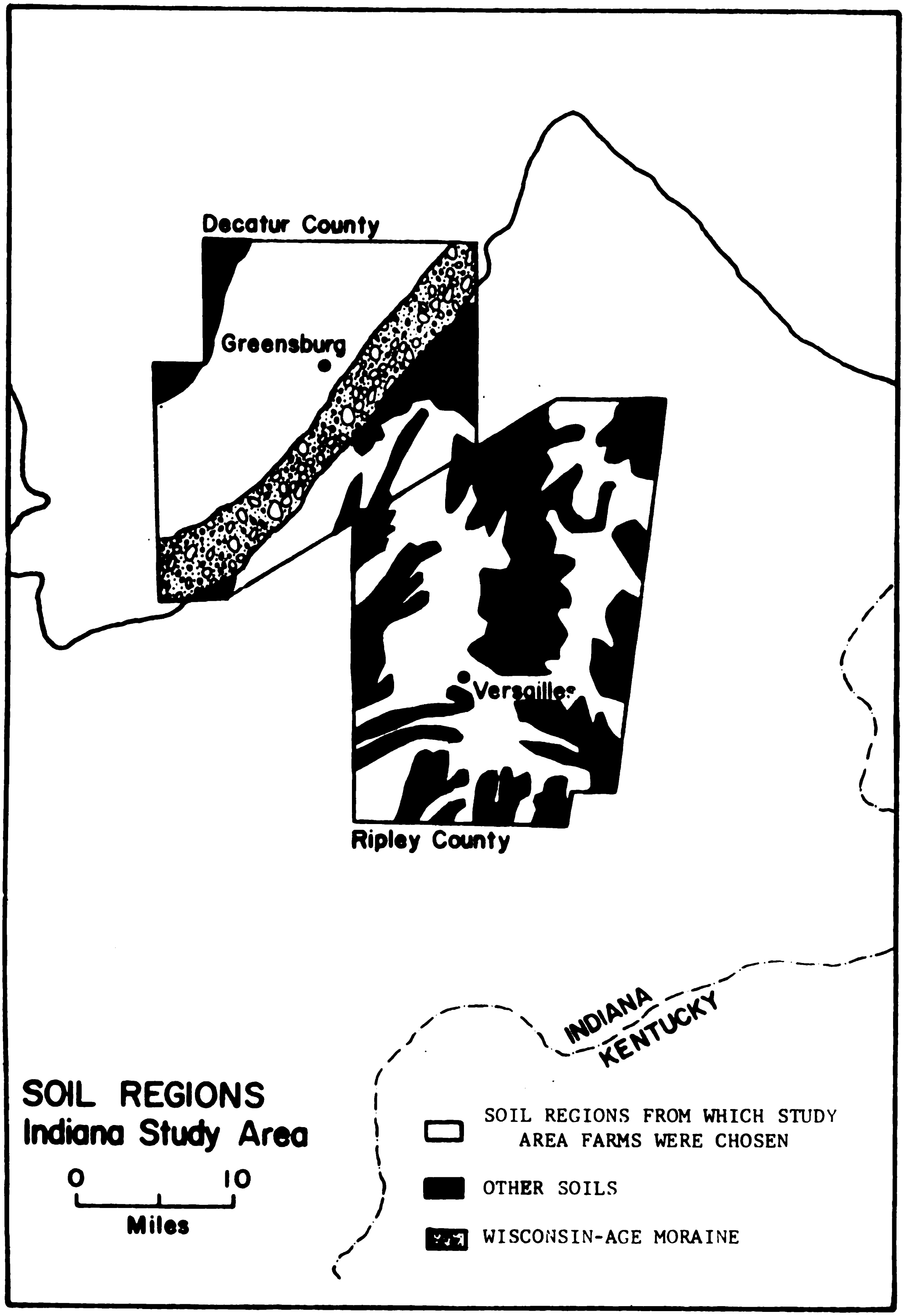

Figure 3. SOIL REGIONS Indiana Study Area. (Source: Bushnell, A Story of Hoosier Soils, Peda-Products, West Lafayette, Indiana, 1958.)

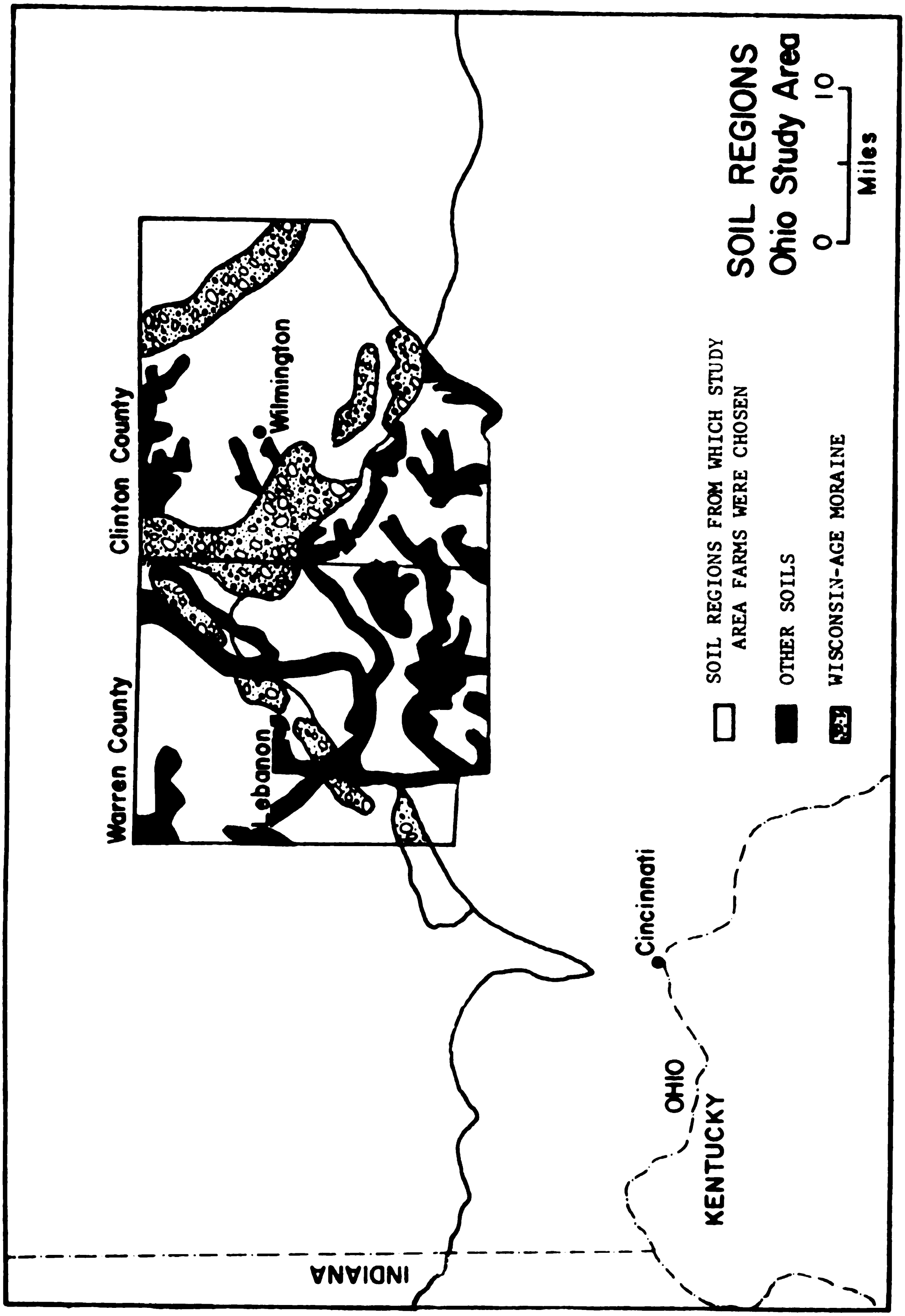

Figure 4. SOIL REGIONS Ohio Study Area. (Sources: Ohio Department of Natural Resources, Progress Report 13, An Inventory of Ohio Soils: Clinton County and Progress Report 24, An Inventory of Ohio Soils: Warren County.)

exhibited between the adjacent contrasting regions and to determine which factors varied significantly in relation to differences in the soils. In testing the factors of agricultural systems, it seemed best to relate them to a sample of individual farms in each of the study areas and to statistically analyze the findings concerning each sample group of farms.

The initial step in the collection of data was the selection of farms in each region of the study areas. A system of coordinates 100 by 100 was placed on a map of each region. The individual farms were located by selecting a pair of two digit random numbers from a table of random numbers. Each coordinate value was chosen independently of the other values obtained. One random number within the range of the coordinate values of the Y-axis (1-99) and the other within the range of the coordinate values of the X-axis (1-99) located the sample farms. A group of twenty-five farms was selected in each of the six regions chosen for the study (see Figures 5,6, and 7.)

The farms chosen as the sample group in each region met certain criteria to be a part of the group: each farm was located on soils indicated as being part of the study area; each farm was functioning as a farming operation; and each farm was run by a full-time farm operator. If a farm did not meet these standards,

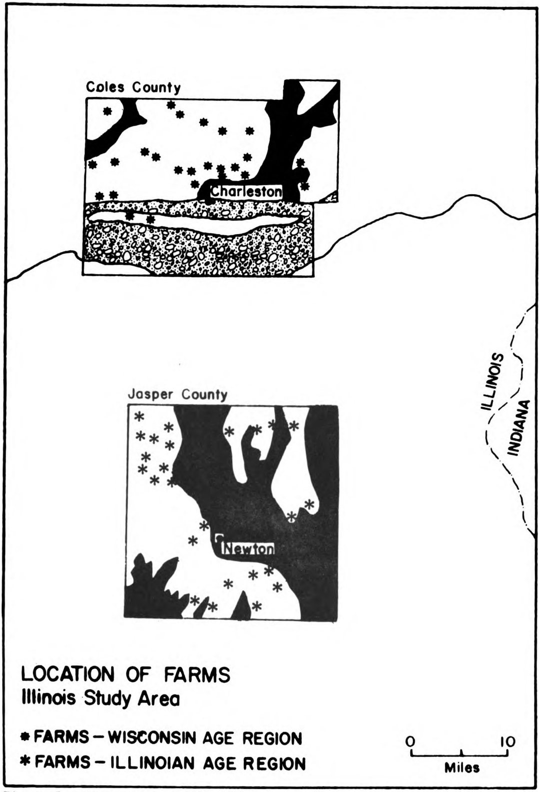

Figure 5. LOCATION OF FARMS Illinois Study Area.

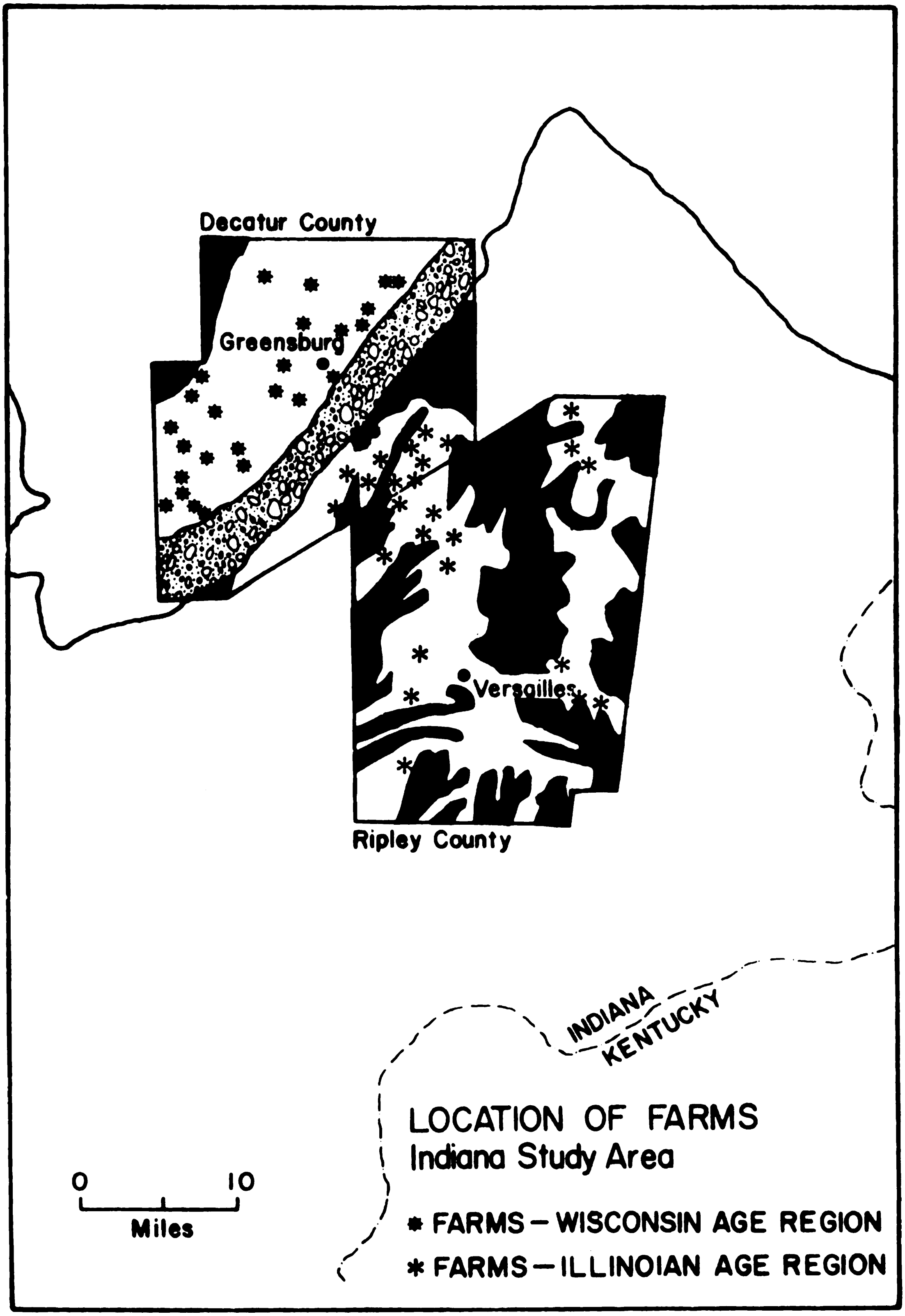

Figure 6. LOCATION OF FARMS Indiana Study Area.

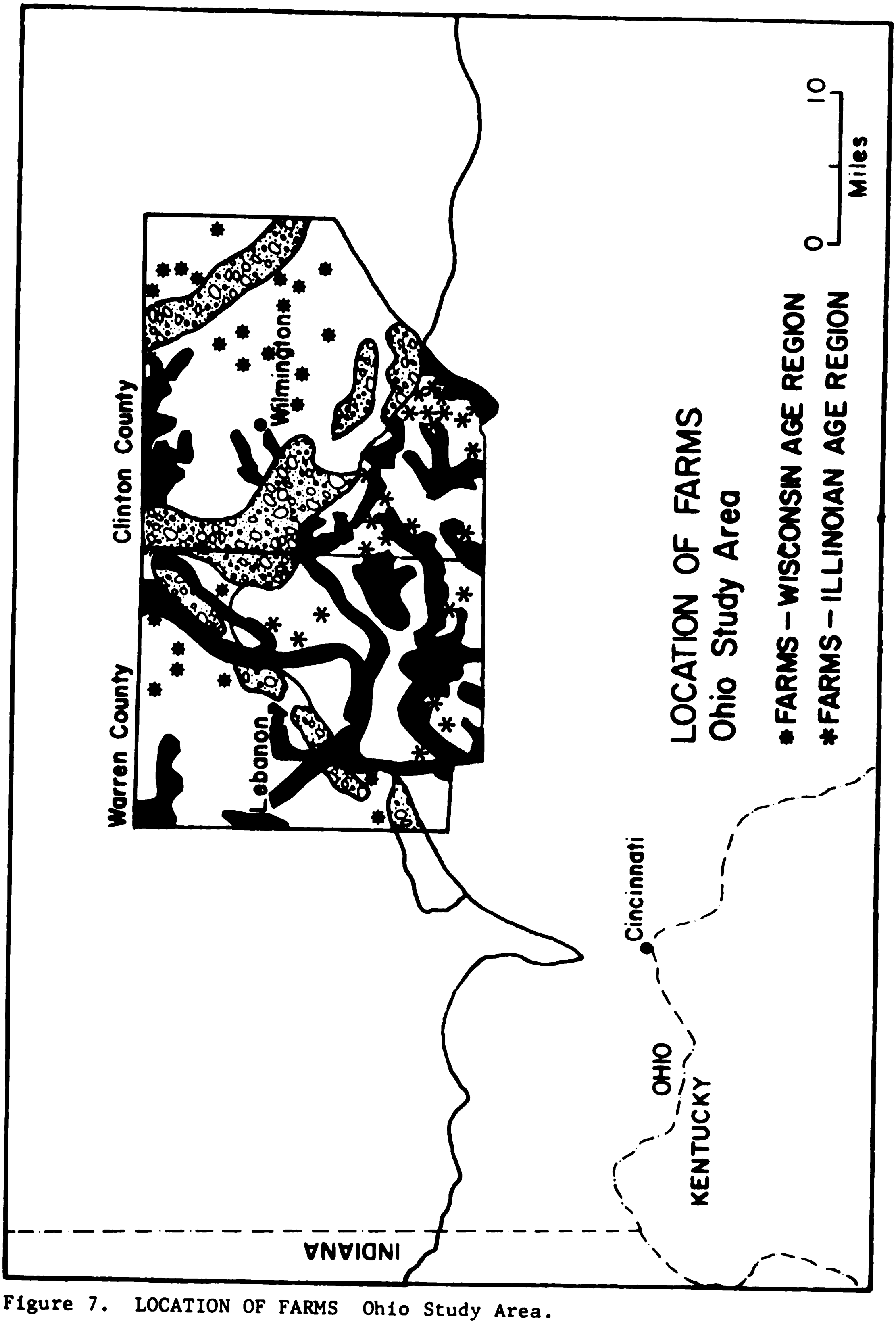

Figure 7. LOCATION OF FARMS Ohio Study Area.

it was eliminated and another was chosen at random to retain a sample group in each region of twenty-five farms. Full-time farm operators were defined in this study as those farmers doing eight or more months of farm work each year with no regular non-farm work during this period.[30] Farm work was defined as all work done in producing agricultural products on the farm unit operated, either for home use or for sale.[31]

It was felt that studying only full-time farmers would focus more directly on the important variables of this study. Wills and Koeller[32] stated that although full-time farmers varied widely in age, size of farm, and tenure status, they had one feature in common--each one devoted all of his time to farming. His interests were in improving and maintaining the fertility of the land and in establishing productive systems of farming that made full use of labor and other resources.

According to Sitterley,[33] part-time farming often accelerated the trend toward farm retirement. Hathaway

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30. J.E. Wills and H.L. Koeller, Employment and Income of Rural Families in Southern Illinois, University of Illinois, Agricultural Experiment Station Bulletin 580, 1954.

31. Ibid.

32. Ibid.

33. J.H. Sitterley, "Some Factors Affecting the Rate of Retirement of Farms in the Submarginal Land Area in Ohio," Journal of Farm Economics, vol. 26 (1944) pp. 737-753.

and Waldo[34] noted that once farm operators became established in a relatively well paying non-farm job, many concluded the income from their farm was not sufficient to pay for the work involved in multiple jobholding. Once the off-farm job became a full-time job, it became a way out of agriculture for most farm operators. It was reasoned that farm operators in the process of leaving farming did not afford a true indication of agricultural production capability or land value and would unnecessarily distort data analysis. From the writer's own experience in Kalamazoo County, Michigan, in 1969, it appeared that part-time farmers spent much less capital and labor in an effort to maintain crop production or to improve farming operations than the full-time operators who engaged in agriculture to earn a living.

Once the sample group of farms was established in each of the study areas, soil data were collected for each farm. Basic data were gathered from soil maps and information in county soil surveys for each of the study areas. More detailed soil data on soil pH, and nitrogen, phosphorus, and potassium content were collected for each farm participating in the soil testing programs of the Cooperative Extension Service. This data helped

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34. Dale E. Hathaway and Arley D. Waldo, Multiple Jobholding by Farm Operators, Michigan State University, Agricultural Experiment Station, Research Bulletin 5, 1964.

to indicate the general soil fertility level and basic productive capacity.

The soil data were incorporated into the Storie Index[35] which gave a value to each soil type relative to other soils for general agricultural purposes. The index was based on three characteristics and conditions of the soils. The first factor considered the characteristics of the profile, the parent material, the mode of formation, and the age or degree of profile development. From Storie's information, the Wisconsin age soils received from 80 to 95 percent rating while the Illinoian age "planosolic" soils received a 50 percent rating. The second factor considered the texture of the surface soil. Silt loam and loam received a 100 percent rating while silty clay loam received a 90 percent rating. The third factor considered the soil modifying conditions of drainage, pH, and fertility. Soils were assigned percentage ratings according to Table 1. Multiplying the values of the three factors together gave an index rating for each soil type. Each index rating was multiplied times the acreage of that soil type on a farm to arrive at an index for the whole farm. The total index was divided by the total farm

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35. R.E. Storie, An Index for Rating the Agricultural Value of Soils, California Agricultural Experiment Station Bulletin 556, 1933.

Table 1. Soil Modifying Conditions:
Percentage Values According to Storie (1933)

Drainage (including artificial drainage)		Acidity (pH)		Fertility	
Good	90-100%	Neutral (7.0)	95%	Very low	60%
Fair	80-90	Slightly acid (6.0-6.5)	85	Low	70
Poor	40-60	Moderately acid (5.0-6.0)	75	Moderate	80
Very Poor	10-40	Strongly acid (4.5-5.0)	65	High	90
		Very strongly acid (4.5)	60	Very high	100

acreage to attain a final farm rating value. The farm rating for each farm then was compared to the other farms in each study area using an analysis of variance test at a .01 level of significance. It was hoped that the Storie Index would more clearly indicate the contrast in soil capabilities between regions, despite requiring an empirical evaluation on the part of the observer. It seemed to be a relatively satisfactory method of assigning a basic numerical value, the farm rating, to each farm as a basis for comparing soil capacities.

Data on the production aspects of each farm were gathered from records in the Agricultural Stabilization and Conservation Service office in each county and from direct interview of the individual farm operators. Units of operation were compared rather than units of ownership because it was felt that land owners might rent land to others or from others. Thus, operators might be owners, part-owners, or tenants.

Information was collected on how the land on each farm was being utilized. The size of the farm was recorded along with percentage figures and acreage totals for: the amount of land on the farm in cropland, the amount of cropland being used for crops, the amount of cropland used only as pasture, the amount of noncropland used only for pasture, the amount of land untilled, the amount of land uncleared, idle, or used for buildings, the amount of woodland, and the amount of woodland used as pasture. It was felt that these figures would help to indicate how fully the land on each farm was being utilized for agricultural production. It was expected that there would be a significant difference between the contrasting soil regions in each study area in the percentage of land on the farms allocated for various uses. The factors measured were expected to show a more intensive use of land on the Wisconsin age soils and a less intensive land use on the Illinoian age soils. The percentage figures of land use for each of the study areas were analyzed using the analysis of variance test at a .01 significance level.

The types of crops grown also were studied. The acreage for each crop was recorded along with the percentage of total cropland for each crop. Yields per acre for each crop were collected. The amount of fertilizer applied per acre was recorded for each crop. The yields were evaluated in terms of fertilizer applied. It was felt that more fertilizer would be necessary on the "planosolic" soils to reach yield levels comparable to those on Wisconsin age soils. It was anticipated that farms on the "planosolic" soils would have more soybean acreage and a higher percentage of land devoted to soybeans, while farms on the Wisconsin age soils would have more corn acreage and percentage of land devoted to corn.[36] It was believed that crop yields would be higher on the Wisconsin age soils. Crop yields, percentage of cropland devoted to each crop, and fertilizer application rates were analyzed for each of the three study areas using the analysis of variance test at a .01 significance level.

The crop rotation system employed by each farm operator was evaluated using an index system devised by Salter and his associates.[37] The soil productivity index for a given crop was designated as the approximate change in the productive capacity of the soil caused by growing each crop for a single year. It was used to measure the balance between the favorable and unfavorable effects of a crop on the capacity of the soil to produce. Crops in rotations were evaluated using the ratings in Table 2. Adjustments were then added for each 200 pounds average commercial fertilizer applied per acre (0.125.)[38] The index system was applied to the rotation system used on each farm in the

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36. J.C. Weaver, "Changing Patterns of Cropland Use in the Middle West," Economic Geography, vol. 30 (1954) pp. 1-47.

37. R.M. Salter, R.D. Lewis, and J.A. Slipher, Our Heritage--the Soil, Ohio Agricultural Experiment Station Bulletin 175, 1936.

38. Ibid. Results of experiments in Ohio showed this value was a fair allowance for fertilizer applications.

Table 2. Rating Values for Crops Grown in Rotation

alfalfa, two years in row	+3.0
alfalfa, one year in row	+2.0
clover	+2.5
timothy	0.0
soybeans, seed	0.0
oats, barley, and wheat	-1.0
corn	-2.0

study group. It was anticipated that the soil productive balance would be higher or positive on the Illinoian age "planosolic" soils because of the lower natural fertility levels and lower or negative on the Wisconsin age soils because of "short cuts" in the rotation scheme due to higher natural fertility levels. The Salter index was analyzed using the analysis of variance test at a .01 significance level for each of the study areas.

Data on farm labor were collected from the individual farm operators. The number of farm workers on each farm and the composition of the labor force were examined to determine the number of family laborers and the number of non-family laborers. The amount of farm work was measured by months and fractions of a month. The total months of labor applied to each farm were calculated by adding the months of work for each laborer on the farm. It was expected that more work would be applied to the Illinoian age soils to produce yields comparable to those on the Wisconsin age soils. These farm labor factors were analyzed using the analysis of variance test at a .01 significance level.

Government subsidy programs were examined to determine what influence they had on the size of non-cropland acreage on each farm. It was suggested that more noncropland acreage, as a part of the land use pattern on farms in a region, could be attributed to subsidy programs than to soil aspects. Diverted acres as a percentage of total farm acreage was evaluated using the analysis of variance test at a .01 significance level.

Land value per acre for the sample farms was secured from tax records at the county assessors office in each county of the study area. The dollar value of land per acre was the assessed value of land for tax purposes. It was expected that this figure would show significantly higher values for the farms on the younger soils and lower values for the farms on the older "planosolic" soils. Thus, land values would tend to reflect productivity levels. The land value per acre was evaluated for each of the study areas using analysis of variance at a .01 significance level.

In addition to the factors examined using the analysis of variance test, the Chi-square test was used to determine if there was a significant difference between adjacent contrasting soil regions for: the presence of artificial drainage, the type of artificial drainage, the presence of a full-time hired hand, the status of the farm operator (owner, part-owner, tenant), changes in farm size, and changes in cropland size. The Chi-square tests were conducted at a .01 significance level.

It was hoped that this study would contribute the following:

1. A reiteration of the value of using soil data to verify the existence of contrasting physical regions;
2. A better insight into the role of physical factors, especially soils, in influencing differences in agricultural systems;
3. An indication of the factors within the agricultural systems on could expect to vary significantly with differences in the physical environment;
4. The need for further studies of this type in other areas to show the role of soils in land use patterns and agricultural systems.

CHAPTER II

THE RELATIONSHIP OF SOIL FORMING FACTORS IN THE STUDY AREAS AND THE RESULTANT SOILS

The physical environment in each of the three study areas is one of similarity rather than of contrast. Except for the soil factors, each of the study areas appears to be relatively uniform from a physical standpoint. The contrasts in soils thus become the focal point of this study and must be considered in detail. Within the study areas, the soil forming factors of climate, vegetation, topography, and parent material are of relatively comparable influence. Variation in the time factor between the adjacent regions in each area makes this factor of primary importance in soil development.

Climate

Temperature and precipitation can be important climatic forces exerting direct influences on soil development.[1] In the study areas, the temperatures of the darker soils of Wisconsin age are warmer than those of the lighter colored "planosolic" soils of Illinoian

1. United States Department of Agriculture, Soil Survey, Clinton County, Ohio, Soil Conservation Service, Series 1958, no. 23, 1962, p. 50.

age. Poor drainage on the "planosolic" soils causes much surplus water which does not soak into the soil but must be evaporated.[2] The "planosolic" soils seem to remain colder in spring because drainage is less than adequate while the younger soils warm more rapidly because of better natural drainage or successful artificial drainage.

The extent and intensity of processes in soil formation are closely related to the magnitude and duration of soil temperatures above freezing. Most soil-forming processes function only when temperatures are above freezing and tend to increase with higher temperatures.[3] Thus, the processes relate to the length of the growing season. Within the confines of the areas of this study, the growing season is essentially uniform (see Table 3.)

Precipitation largely governs the supply of moisture at the soil surface. Runoff, erosion, infiltration, and leaching are closely related to the total quantity of precipitation, the rate at which it reaches the surface and the seasonal distribution.[4] Precipita-

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2. R.C. Ross and H.C.M. Case, Types of Farming in Illinois: An Analysis of Differences by Areas, University of Illinois, Agricultural Experiment Station Bulletin 601, 1956, p. 14.

3. University of Wisconsin, Soils of the North Central Region of the United States, Agricultural Experiment Station Bulletin 544, North Central Regional Publication 76, 1960, p. 12.

4. University of Wisconsin, op. cit., p. 10.

Table 3. General Climatic Data for Study Areas[5]

County	Average Growing Season (days)	Average Annual Temp. (°F.)	Average Mean-July Temp. (°F.)	Average Annual Precip. (inches)	Average Precip. May-Sept. (inches)
Clinton, Ohio	170	53.3	75.2	44.3	19.4
Warren, Ohio	171	52.0	73.7	39.3	18.2
Decatur, Indiana	177	53.4	75.9	41.1	18.0
Ripley, Indiana	175est.	54.0est.	76.0est.	40.5	18.6
Coles, Illinois	173	53.6	76.9	38.6	19.0
Jasper, Illinois	184	55.5	77.5	39.2	18.3

5. United States Department of Commerce, Climatic Summary of the United States--Supplement for 1951 through 1960, Washington, D.C., 1964.

tion in the study areas is relatively uniform, ranging from an annual average of 38.6 inches in Coles County, Illinois, to 44.3 inches in Clinton County, Ohio. About one half of the precipitation falls during the growing season (May to September) with averages for this period varying from 18.0 inches in Decatur County, Indiana, to 19.4 inches in Clinton County, Ohio. The rainfall is fairly well distributed over the growing season and generally is enough to produce good crops. Climate affects soils through a combination of temperature and precipitation on a broad areal scale. However, even relatively small differences in climate can cause pronounced differences in the development of soils. While it is recognized that average figures do not begin to show the variations in climate that can exist over short distances, certainly among the three areas of this study no one area appears to exhibit a climatic advantage or disadvantage in relation to the other areas (see Table 3.) The fairly uniform climate throughout the study areas seems to indicate that soils differ because of local differences in the other soil forming factors.

Vegetation

Two general types of vegetation are recognized in the study area, a prairie or grassland type and a forest type. While soil development is more intense under trees, the same type of weathering processes occur under both forest and grassland vegetation. Upland soils formed under grassland have relatively large amounts of organic matter and can be considered productive soils. Forest soils developed on uplands are lighter colored, contain less organic matter, and are somewhat less productive than grassland soils.[6] In the Ohio and Indiana study areas, all soils have developed under forest vegetation. Vegetation is a common factor throughout the contrasting adjacent soil regions and appears to have relatively little effect on differences in soils.

The two counties selected for the study area in Illinois contain both soils developed under grassland vegetation and soils developed under forest vegetation. The grasslands predominate in both counties, so the sample group of farms includes only those farms with grassland soils, in order to maintain vegetation as a constant factor. Examining soils influenced by only one general vegetation type in each study area appears to be a method of eliminating an extraneous variable which could affect the degree of contrast being measured.

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6. University of Illinois, Coles County Soils, Agricultural Experiment Station Soil Report 44, 1929, p. 5.

Topography

Topography, both locally and regionally, has a governing effect on drainage, runoff, and erosion and thus contributes to the formation and distribution of soils.[7] More moist conditions occur more often and for longer periods on very gentle slopes or near level areas due to greater intake of precipitation and reduced runoff. Such a situation is conducive to greater weathering rates and to restricted aeration and oxidation. Soils on upland sites, inward from the margins of a slope, often are soils of considerable age with hydromorphic or "planosolic" variants in the central, poorly drained parts of the wider uplands.[8] The soils of all three study areas can be placed in this upland location, thus weathering rates and moisture conditions can be considered similar.

The topography throughout all three study areas is essentially flat land; slopes are less than five percent. Runoff and erosion are reduced to comparatively insignificant rates while infiltration and soil formation rates are greater than on neighboring soils on slopes. The natural drainage is the predominant

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7. University of Wisconsin, op. cit., p. 10.
8. Brian T. Bunting, The Geography of Soil, Aldine Publishing Company, Chicago, 1967, p. 71.

topographic factor which seems to vary between adjacent regions in each of the study areas. The difference in drainage can be attributed to the internal obstructions found in the claypan or fragipan horizon of the "planosolic" soils on the older Illinoian till. The pan characteristic is not developed in the soils on the younger Wisconsin till. All three study areas have imperfectly, poorly, or very poorly drained soils.

Parent Material

Two major sources of soil parent material are recognized in the study areas. One is older Illinoian age till deposited in near level till plains. The till has been modified greatly by deep leaching of carbonates and other weatherable minerals. The till averages from ten to fifteen feet in depth, with some locations being shallower and a few deeper. The other parent material is younger Wisconsin age till deposited in near level to gently sloping till plains. The till has been less altered by weathering than the Illinoian till and can be considered more naturally fertile.[9] The boundary between the two parent materials is often abrupt with a sharp drop from gently rolling lands on the younger till to a lower, near level surface on the older till.

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9. United States Department of Agriculture, *op. cit.*, p. 49.

Both parent materials are glacial tills of loam or silt loam texture with high available moisture storage capacity and mixed mineralogy. Both tills were calcareous and relatively well supplied with plant nutrients when deposited. A shallow layer of loess, not over five feet thick at any site, covers the till throughout the study areas. The thin loess cover in the study areas is material that was deposited slowly and in small amounts which weathered while being deposited. Soils are strongly to very strongly developed where weathering occured during deposition of the loess in areas underlain by materials of Illinoian age. These older materials probably aided in accelerating soil formation.[10] The two parent materials seem to be essentially similar in texture, in mineralogy, and in structure. The age of the two tills and the degree of soil development on them varies markedly, however.

Time

The time factor in soil formation usually is not measured in years, but in degree of soil development. Clearly, a shorter period of years in which the whole complex of environmental influences is changing has far

10. J.B. Fehrenbacher, B.W. Ray, and J.D. Alexander, "Illinois Soils and Factors in Their Development," The Quaternary of Illinois, University of Illinois, College of Agriculture, Special Publication 14, 1968, p. 166.

more effect on soil development than a longer period of years in which factors do not change but create a state of equilibrium.[11] Development is more rapid in a humid climate which supports a good vegetative growth, as in the study areas, than in drier climates with sparse vegetation. Leaching of plant nutrients is more rapid in coarse textured, permeable parent material than in fine textured, slowly permeable parent material. Acid soils develop more rapidly from materials low in carbonates than from carbonate rich material. Both the Illinoian till and the Wisconsin till of the study areas were relatively rich in carbonates prior to leaching.

On stable landscapes, such as the interfluve divides where the soils of this study are located, soils are more strongly developed, more highly leached, and have stronger horizon differences with increased time of exposure to weathering processes.[12] The effect of time can be shown by a lack of dark-colored soils, by a more highly dissected landscape, and by areas of claypans in near level topography associated with the

11. Bunting, op. cit., p. 83.
12. J.B. Fehrenbacher, G.O. Walker, and H.L. Wascher, Soils of Illinois, University of Illinois, Agricultural Experiment Station Bulletin 725, 1967, p. 39.

older soils of Illinoian age.[13] Prolonged weathering has decomposed primary soil minerals and has moved large amounts of clay from the surface to the subsoil. The relatively young Wisconsin age upland soils are evidenced by a low degree of stream dissection, by a high proportion of dark colored soils, and by the absence of claypans. Deep intense weathering may result in the decomposition of all minerals except those most resistant to weathering. Even the Illinoian age "planosolic" soils have not reached this stage as yet.

The parent materials in the study areas are of two general age groups, Illinoian age and Wisconsin age. A number of dates have been assigned to these two glacial stages in the literature, measured in years before the present. The older materials are of the Illinoian glacial stage modified somewhat by a thin loess deposited partly during the Wisconsin stage. Bushnell[14] assigns an age of 700,000 years old to the Illinoian deposits, while Ray[15] gives a date of 22,000 years ago for the initiation of weathering and development of the "planosolic" soils. More frequently estimates range from 100,000 to 200,000 years old for the

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13. T.M. Bushnell, A Story of Hoosier Soils, Peda-Products, West Lafayette, Indiana, 1958, p. 5.
14. Bushnell, *op. cit.*, p. 9.
15. Ray, *op. cit.*

Illinoian stage.[16] Bushnell[17] claims the oldest Wisconsin stage deposits to be 180,000 years old, but Ray[18] places an age of 12,000 years ago for the development of Wisconsin age soils since the end of loess deposition. More exact dating of materials embedded in the terminal moraines in Ohio and Indiana have placed the furthest advance of the Wisconsin glacial stage about 20,000 years ago (see Table 4.) However, the actual age of the glacial stages in years does not appear to be important. Rather, the relative age of the two tills and the relative development of soils appear to be the key factors of contrast between the two regions in each study area. It is the relative age of the two parent materials which has influenced the development of much more weathered, leached, and acid soils in the older Illinoian material and much less weathered, less leached, and less acid soils in the younger Wisconsin material.

Resultant Soils--General

Varying influences of the five soil forming factors can result in the development of soils which differ in their productivity or natural fertility levels, in their ability to respond to fertilizer treatment, and in their

16. United States Department of Agriculture, op. cit., p. 51.
17. Bushnell, op. cit., p. 9.
18. Ray, op. cit.

Table 4. Dates of Furthest Advance of Wisconsin Glacial Stage, by Carbon-14 Dating--Ohio[19] and Indiana[20]

Turtle Creek Township, Warren County, Ohio	19,621 ± 372 years ago
N. of Sharonville, Butler County, Ohio	20,500 ± 800
W. of Adelphi, Ross County, Ohio	17,292 ± 436
W. of Chillicothe, Ross County, Ohio	18,050 ± 400
W. of Chillicothe, Ross County, Ohio	18,000 ± 400
Near Terre Haute, Vigo County, Indiana	21,400 ± 650
Near Rockville, Parke County, Indiana	20,500 ± 800
Greencastle, Putnam County, Indiana	19,500 ± 800
S. of Connersville, Fayette County, Indiana	20,000 ± 500

19. Jane L. Forsyth, "Age of Wood from Wisconsin Terminal Moraine Near Adelphi, Ross County, Ohio," Ohio Journal of Science, vol. 65 (1965) pp. 159-160; Jane L. Forsyth, "Contribution of Soils to the Mapping and Interpretation of Wisconsin Tills in Western Ohio," loc. cit., pp. 220-227; and Dale Garner and Jane L. Forsyth, "A Radiocarbon Date From the Hartwell Moraine, Warren County, Ohio," loc. cit., pp. 94-95.

20. W.J. Wayne, The Crawfordsville and Knightstown Moraines in Indiana, Indiana Department of Conservation, Geological Survey of Progress 28, 1965, p. 9.

structure and moisture content. These differences can in large part determine the supply of nutrients to growing plants, the availability of moisture for plant demands, and the development of plant roots in sufficient quantities. Limiting morphological features, such as claypans and fragipans, can be found on nearly level drainage divides, given proper time for formation and the proper combination of climate and parent material factors. These pans have high moisture storage capacity due to the high content of finer textured materials. However, weakly developed structure in these pans restricts root penetration and restricts moisture utilization.[21] Soils which are similar, except that they lack the claypan or fragipan, usually have adequate root penetration and allow more nutrients and moisture available for plant growth.

The five factors of soil formation, especially time, have contributed to apparently contrasting soils in the adjacent regions of the three study areas. The soils developed on the Illinoian till, the "planosolic" Alfisols, are the central focus of this thesis. Various factors of agricultural systems are compared between younger Wisconsin age soils and the "planosolic" soils. The "planosolic" soils form one of the most

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21. Fehrenbacher, Ray and Alexander, _op. cit._, p. 173.

distinct and extensive soil groups in the south-central part of the midwest. They are silt loams with a compact subsoil and low natural fertility, and are limited to near level or gently sloping topography. The surface drainage is deficient and internal drainage is slow, due to the high percent of clay in the subsoil.[22] The compact, fine textured pan in the B horizon represents a large and sharp increase in clay content from the A_2 horizon. Plant roots penetrate the pan only along cracks and in small numbers, so that plants must obtain moisture from the surface soil. During wet periods water accumulates above the claypan and can stand for several days after a heavy rain. Periods of rainfall deficiency can easily dry out surface horizons, so that crops suffer after ten to fifteen days without precipitation. The critical moisture problem makes timing of agricultural operations very important.

The "planosolic" Alfisols are low in productivity, have low fertility levels, and need artificial drainage to be utilized for agriculture. Organic matter once accumulated at the surface has been dissipated. The basic cations have essentially been removed, leaving a strongly acid condition with low base saturation. Large amounts of fertilizer are needed for satisfactory

22. University of Wisconsin, op. cit., p. 66.

crop yields. The "planosolic" soils can be drained by surface ditches and they do respond to ample amounts of lime, nitrogen, phosphorus, and potassium.[23] The "planosolic" soils have lower percent organic matter, lower cation exchange capacity, and lower percent base saturation in the A horizon, and greater clay concentration in the B horizon than the Wisconsin age Alfisols and Mollisols being compared to them. The Wisconsin age soils generally are less acid, more fertile, higher in productivity, and lack the claypan subsoil horizon.

Resultant Soils--Illinois Study Area

The "planosolic" Alfisols of the Illinois study area are known locally as the "common hardpan prairie."[24] The general profile is distinguished by a tight yellowish gray mottled clay subsoil at a sixteen to twenty inch depth. Water passes slowly through this claypan subsoil making it sticky and plastic when wet. It is stiff and hard when dry. The "planosolic" soils in Illinois developed under grassland vegetation in two and one half to four feet of loess over Illinoian till. The soils are characterized by their low inherent fertility due to prolonged weathering and leaching.[25]

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23. Ray, op. cit.

24. Cyril Hopkins and James Pettit, The Fertility of Illinoian Soils, University of Illinois Agricultural Experiment Station Bulletin 123, 1908, p. 210.

25. Fehrenbacher, Walker, and Wascher, op. cit., p. 11.

They are strongly to very strongly acid, with natural pH values often below 5.0. Nitrogen, phosphorus, and potassium supplying powers are low. The soils need improved drainage, large amounts of fertilizer and lime, and well planned crop rotations to be useful for crop production.

The Cisne silt loam soil type is the most extensive soil, comprising nearly three-fourths of the "planosolic" soil region of the Illinois study area. Slopes are less than one and one-half percent, permeability is very slow due to the highly plastic and impervious claypan, and the soil is strongly acid. Nitrogen, phosphorus, and potassium levels are low compared to Wisconsin age soils (see Table 5.) Poor natural drainage can be alleviated only by surface drainage using furrows and ditches. Lime and fertilizers are needed in large quantities, but response is less than on other soils of the region.[26]

The Hoyleton silt loam soil type covers about one-fourth of the region and occurs on slightly sloping sites. Slopes range from one and one-half percent to three and one-half percent, permeability is slow due to the compact, plastic claypan subsoil, and the soil is strongly acid. Nitrogen, phosphorus, potassium, and

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26. University of Illinois, Jasper County Soils, University of Illinois Agricultural Experiment Station Soil Report 68, 1940, p. 9.

organic matter content are low, similar to that of the Cisne series.[27] Imperfect drainage is the result of a combination of good surface drainage and slow subsurface drainage. As in the Cisne series, tile drains do not function adequately because of the tight subsoil. Open ditches operate successfully to remove excess water.

Soil improvements to ameliorate the relatively poor natural state of these "planosolic" Alfisols involves overcoming a complex of problems. Evaporation is much more effective in removing available moisture from these light colored soils than from the darker Wisconsin age soils in the Illinois study area.[28] Root development is restricted to the A_2 horizon, due to the tight subsoil, unless proper fertilizer treatment is applied. The shallow root system increases the hazard of drought damage to crops. Adequate amounts of fertilizer can improve root penetration and reduce the drought threat.[29] Adequate ditch drainage must be installed to remove excess water which can accumulate, especially in spring. Lime must be applied to increase the soil pH, and organic matter, nitrogen, phosphate,

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27. Ibid., p. 15.

28. Ross and Case, op. cit., p. 11.

29. J.B. Fehrenbacher, B.W. Ray, and J.D. Alexander, "Root Development of Corn, Soybeans, Wheat, and Meadow in Some Contrasting Illinois Soils," Illinois Research, University of Illinois Agricultural Experiment Station, Spring, 1967, pp. 3-5.

and potash are needed to overcome deficiencies. The use of recommended amounts of lime and fertilizer can maintain fertility levels and represents the key to good management of a crop rotation system in the region.[30] While most crops respond well to soil treatments, yields are only moderately high under high level management.[31]

As one passes from the older Illinoian soils to the younger Wisconsin soils, there is an increase in the nutrient content of the soil. Higher amounts of phosphorus and potassium in the grassland soils of the Wisconsin glaciation compared to the Illinoian glaciation are due in large part to the loss by longer weathering and leaching on the Illinoian till. Potassium is more subject to loss from weathering and leaching than phosphorus, and thus a better measure of the contrast between the two soil regions[32] (see Table 5.)

The Wisconsin age Mollisols of the Illinois study area are highly productive soils relative to the "planosolic" soils to which they are compared. The generalized profile is a friable very dark brown to black silt loam or silty clay loam horizon over a subsoil of

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30. Eric Winters, "The East-Central Uplands," Soil, Yearbook of Agriculture, 1957, United States Department of Agriculture, Washington, D.C., p. 571.

31. Fehrenbacher, Walker, and Wascher, op. cit., p. 11.

32. Hopkins and Pettit, op. cit., p. 210.

Table 5. Comparative Nutrient Content of Major Soil Series in Illinois Study Area[33] (available plant nutrients, pounds per acre)

Series	N	P	K	Lime needed
Cisne	58	8	62	2-5 tons/acre
Flanagan	101	12	91	rarely
Drummer	157	20	88	none

33. *Ibid*., p. 202.

silty clay loam or heavy silty clay loam. The claypan feature of the "planosolic" soils is absent. These soils developed in one and one-half to five feet of loess over Wisconsin age loam till. The soils are characterized by their very high inherent fertility. The supplying power for nitrogen, phosphorus, and potassium is the highest in the state.[34] Generally, these Mollisols have medium to slight acidity, with pH values around 6.5. Still, the soils respond to lime and fertilizers.

The Flanagan silt loam and the Drummer silty clay loam are the two major soil types of this region of the Illinois study area. The Drummer soil has slopes of less than one percent, moderate permeability, and poor natural drainage. The Flanagan soil has slopes of one to three percent, moderate permeability, and imperfect natural drainage. Both soils have relatively loose subsoils which permits better root penetration than in the "planosolic" soils in the contrasting region. The consequence is much better drought resistance on the Flanagan and Drummer soils. Drainage facilities are needed over most of the region, but in contrast to the Cisne and Hoyleton soils, tile drains function well

34. Fehrenbacher, Ray and Alexander, "Illinois Soils and Factors in Their Development," loc. cit., p. 174.

and drainage is relatively easy and highly profitable to install.[35]

Soil improvement in this region is a much less complex task than in the "planosolic" soil region. The soils are rich in organic matter, have much greater amounts of available nitrogen, phosphorus, and potassium, and need less lime to correct acidity than on the older soils[36] (see Table 5.) Management involves maintaining proper fertility levels, tile drainage, and adequate tillage to maintain good physical conditions. The high available moisture storage capacity and the response of crops to relatively small amounts of fertilizers make these soils very highly productive under a high level of management.[37]

Resultant Soils--Ohio and Indiana Study Areas

The Illinoian age "planosolic" Alfisols of the Ohio and Indiana study areas are known locally as the "crawfish lands" or the "pin-oak flats."[38] The general profile is distinguished by a firm, compact mottled silty clay loam subsoil at a twelve to sixteen inch depth. The subsoil has the effect of retarding air and moisture circulation in the profile. The soils have

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35. Ross and Case, op. cit., p. 11.
36. Ibid.
37. Fehrenbacher, Walker and Wascher, op. cit., p. 9.
38. United States Department of Agriculture, op. cit., p. 1.

developed under forest vegetation in one and one-half to four feet of loess over Illinoian till. The soils are characterized by their low level of fertility due to deep leaching, intense weathering, strong acidity, and the compact subsoil. Nitrogen, phosphorus, and potassium supplying powers are low. Organic matter content also is relatively low. The soils need improved drainage, large amounts of lime and fertilizer, and well planned crop rotations to be useful for crop production.

The Avonburg silt loam soil type developed on flat to gently sloping uplands under imperfect drainage. Slopes are less than five percent; nine-tenths are less than two percent. The soil is very strongly acid, has slow permeability, and has low amounts of nitrogen, phosphorus, and potassium available for crops. The mottled, gray, firm subsoil restricts roots to a shallow to moderate zone.[39] The Avonburg soil requires surface ditches and bedding lands for successful drainage because of the compact subsoil. Tile drains are not recommended. The soil will puddle or clod if worked when wet.

The Clermont silt loam soil type developed on flat uplands under poor drainage; slopes are less than two

39. Ibid., p. 23.

percent. The soil is very strongly acid, has slow permeability, and has only small amounts of nitrogen, phosphorus, and potassium available for crop production (see Tables 6 and 7.) The mottled, thick, plastic silty clay loam subsoil restricts roots to a shallow zone. The very slowly permeable subsoil creates a drainage problem, alleviated by using surface ditches. Drainage is difficult to establish because of the near level surface. Waterlogging in spring can delay soil preparation and planting.

Both the Clermont and Avonburg soils have moderate moisture supplying capacity, low organic matter content, and low natural fertility. Average pH values for natural soil conditions are near 5.0 in the surface and upper subsoil horizons. The structure of the soils can be improved somewhat with legumes and grasses in rotation, usually one year in every three. They badly need lime, fertilizer, and organic matter to be productive.[40] Even with regular lime applications, large amounts of fertilizer, added organic matter, and proper management, the potential is limited.[41]

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40. Ohio Department of Natural Resources, An Inventory of Ohio Soils: Warren County, Progress Report 24, Division of Lands and Soils, 1964, p. 24.

41. United States Department of Agriculture, op. cit., p. 28.

Table 6. Comparative Nutrient Content of Major Soil Series in Ohio and Indiana Study Areas[42] (median values, available plant nutrients, pounds/acre)

Series	K	P	Lime required (% 2 T/A)
Brookston	200	24	16%
Fincastle	140	21	27
Ragsdale	170	30	20
Clermont	95	13	41

Table 7. Percentage of Soil Tests in Low, Medium, High Categories for Potassium and Phosphorus and in Ranges of pH Values[43]

	K			P			pH		
	Low	Med.	High	Low	Med.	High	<5.5	5.5 6.5	>6.5
Brookston	4	29	67	16	46	38	4	62	34
Fincastle	25	52	23	20	51	29	12	60	26
Ragsdale	11	41	48	12	45	43	6	64	30
Clermont	74	19	7	38	49	13	31	54	15

42. J.B. Jones and O.L. Musgrave, Fertility Status of Ohio Soils as Shown by Soil Tests in 1961, Ohio Agricultural Experiment Station Research Circular 118, p. 10.

43. Ibid.

In Ohio and Indiana, as in Illinois, the nutrient content of the soils increases from the Illinoian age soils to the younger Wisconsin age soils. Greater amounts of phosphorus and potassium in the soils of the Wisconsin-aged landscape compared to the Illinoian-aged landscape are due primarily to the loss by greater leaching and longer weathering of the Illinoian till.

The Wisconsin age Alfisols and Mollisols of the Ohio and Indiana study areas are much more naturally fertile soils than the "planosolic" soils to which they are compared.[44] The Wisconsin age soils have developed in one and one-half to five feet of loess over calcareous Wisconsin till. The potassium and phosphorus supplying capacity is relatively high, the soils are medium to low in acidity, productive capacity is high.

The Brookston silt loam or silty clay loam soil type is a dark gray soil occupying slightly depressed areas in the upland. The soil has high organic matter content (greater than three percent in the plow layer), high moisture-supplying capacity, and is well supplied with potassium and phosphorus, making it a highly fertile and very highly productive soil.[45] The soil is poorly drained and permeability is slow, making drainage

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44. United States Department of Agriculture, *op. cit.*, p. 1.

45. Ohio Department of Natural Resources, *op. cit.*, pp. 30-31.

the main problem to overcome. Properly installed tile drains work well. Slopes are under two percent on the Brookston soil. Fertilizers are used to maintain high yields and to maintain the naturally deep rooting zone. Lime is seldom needed because the soil is slightly acid to neutral in reaction.

The Fincastle silt loam soil type is a lighter colored soil than the Brookston soil and occupies near level upland sites with slopes less than five percent; most are less than two percent. The soil has a moderately high organic matter content, medium moisture-supplying capacity, and is less well supplied with potassium and phosphorus than the Brookston soil (see Tables 6 and 7.) Nevertheless, it is a productive soil with proper management.[46] The soil is imperfectly to poorly drained and permeability is slow. However, tile drains work well in reducing the excess water problem. The Fincastle soil responds well to lime, fertilizer, and additions of organic matter.

The Ragsdale silt loam soil type is a dark brown soil occupying near level topography where slopes do not exceed two percent. The soil has high organic matter content, high moisture supplying capacity, and

46. United States Department of Agriculture, <u>Soil Survey of Decatur County, Indiana</u>, Bureau of Soils, 1922, p. 24.

is well supplied with potassium and phosphorus, making it a highly productive soil. The soil is poorly drained and permeability is medium to slow, but tile drains function well. The deep root zone can be maintained with fertilizers while lime can reduce the medium to slight acidity.

The Reesville silt loam soil type is a relatively light colored soil occupying sites with slopes less than two percent. The soil has moderate organic matter content, moderate moisture supplying capacity, and is relatively well supplied with potassium and phosphorus, making it moderately high in productivity.[47] The soil is imperfectly drained and permeability is slow creating a seasonal high water table problem. Tile drains work well in reducing excess water. Lime is needed occassionally to modify the slight natural acidity. The Reesville soil responds well to adequate fertilizer and additions of organic matter to maintain fertility and a moderately deep root zone.

Each of the four Wisconsin age soils in the Ohio and Indiana study areas requires proper management to be productive. Drainage, lime applications, fertilizer applications, and additional organic matter must be

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47. Ohio Department of Natural Resources, op. cit., p. 31.

accompanied by a good crop rotation system and proper tillage to maintain soil structure. Under good management these soils can be highly productive.

CHAPTER III

RELATIONSHIPS OF SOILS TO AGRICULTURAL SYSTEMS IN THE STUDY AREAS

Assuming that the soils of the adjacent regions of each study area contrast in their natural fertility and productive capacity, the relationships of soils to the agricultural systems in each study area should be examined. This subject has been dealt with at length in the literature. Previous studies concerning the study areas and other areas of similar soil contrasts thus will be reviewed. Data on land use, crops, and crop yields for the counties in which the study areas are located also will be presented to lay the foundations for the analysis of data from the sample groups of farms investigated in this thesis.

The types of farming in any area, and thus the agricultural system, is not a haphazard growth, but the result of farmers' efforts to adjust organization and operations to definite factors such as soils.[1] Soils help to set definite limits to agricultural production, determining the extent of choices of farm types feasible in an area. The majority of the more fertile soils

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1. P.E. McNall and W.J. Roth, Forces Affecting Wisconsin Agriculture With Resulting Types of Farming, University of Wisconsin Agricultural Experiment Station Research Bulletin 131, 1935, p.1.

support good agricultural production; land use is adapted to the soil productivity level.[2] The better the soil quality, the more land in an area is in farms.[3] The trend in agricultural land use is towards a concentration of resources and a more intensive use on more fertilie or more level land. Land of poor quality tends to revert to pasture.[4] In fact, according to Hart,[5] land quality appears to be the underlying cause of much land abandonment. Often a long period of underuse preceeds abandonment. Underuse can be measured well by the percent of land on each farm being utilized for agricultural production.

Land Use

Land use by regions in Indiana shows the influence of general land character.[6] However, a closer correlation exists between the characteristics of soil types and their average use. The soils on the flattest land in Indiana tend to retain more of the original forest cover, probably due to the difficulty in draining soils

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2. J.S. Gibson, "Soil Factors in the Character of Land Use in the Tennessee Valley," Economic Geography, vol. 13 (1937) pp. 385-392.

3. Bushnell, op. cit., p. 97.

4. O.E. Baker, "Land Utilization in the United States: Geographical Aspects of the Problem," Geographical Review, vol. 13 (1932) pp. 1-26.

5. J.F. Hart, "Loss and Abandonment of Cleared Farm Land in the Eastern United States," Annals of the Association of American Geographers, vol. 58 (1968) pp. 417-440.

6. Bushnell, op. cit., p. 43.

on the upland divides far from outlets and with claypan subsoils. The tendency is reflected in the allocation of land use in the Illinoian age soil region of southeast Indiana compared to the Wisconsin age soil region in the same general area (see Table 8.) More than fifty percent of the land on the Illinoian soils is in permanent pastures, idle land, timber land or miscellaneous uses, compared to just over twenty-five percent on the Wisconsin age soils.

A further indication of the contrast in land use between the two soil regions in southeast Indiana seems to be evident when comparing the land use statistics for Decatur and Ripley Counties. Although the data are not restricted to the soil types studied in this thesis, they do give a general indication of the degree of contrast between the two adjacent soil regions (see Table 9.) The relatively large difference in cropland harvested, fifteen percent more in Decatur County, seems to imply a more intensive use of land on the younger Wisconsin age soils. Total cropland as a percentage of land in farms adds support to this implication, as Decatur County has seventeen percent more land in cropland. The principle of underuse as stated by Hart[7] seems to apply well to Ripley County because more

7. Hart, op. cit.

Table 8. Allocation of Land Use in Southeast Indiana--
Wisconsin and Illinoian Soil Regions[8]

	Wisconsin	Illinoian
Corn and Soybeans	37%	22%
Small Grains	21	16
Hays	15	11
Pastures	11	22
Idle and Waste	8	9
Timber and Miscellaneous	8	20

8. Bushnell, op. cit., p. 42.

Table 9. Agricultural Land Use Decatur County and Ripley County, Indiana--1964[9]

	Decatur	Ripley
Cropland Harvested as % of Land in Farms	55.6%	40.2%
Cropland Used Only as Pasture as % of Land in Farms	11.1	8.8
Cropland Not Harvested or Pastured as % of Land in Farms	10.4	11.8
Total Cropland as % of Land in Farms	77.1	60.8
Woodland Pastured as % of Land in Farms	6.8	5.7
Woodland Not Pastured as % of Land in Farms	5.8	10.9
Permanent Pasture as % of Land in Farms	5.5	15.1
Total Woodland and Permanent Pasture as % of Land in Farms	18.1	31.7
Average Farm Size--Acres	174.3	117.4

9. United States Department of Commerce, *United States Census of Agriculture 1964*, Bureau of the Census, Washington, D.C., 1966.

than thirty percent of the land in farms is in woodland or permanent pasture while less than twenty percent of Decatur County is devoted to these uses. The average farm size seems to indicate a more efficient use of land in Decatur County than in Ripley County.[10]

The desirable farm size in Illinois is supposed to be somewhat larger than 260 acres, which provides for optimum use of land, labor, and capital.[11] Intensive use of land for agricultural production can still be maintained with such a farm size. The average farm size in Coles County compared to that of Jasper County appears to approximate more closely the optimum size and thus implies a more efficient use of land (see Table 10.) A larger percentage of cropland harvested and a larger percentage of total farm land used as cropland in Coles County tends to support the suggestion that land use is more intensive than in Jasper County. The small percentage of land devoted to woodlands and permanent pasture in both counties reflects the predominance of grassland soils in both regions. It does not seem that Hart's principle of underuse can be applied to Jasper County, from the data presented in Table 10.

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10. M.L. Mosher, <u>Farms are Growing Larger</u>, University of Illinois Agricultural Experiment Station Bulletin 613, 1957, p. 12.

11. <u>Ibid</u>.

Table 10. Agricultural Land Use Coles County and Jasper County, Illinois--1964[12]

	Coles	Jasper
Cropland Harvested as % of Land in Farms	73.4%	67.1%
Cropland Used Only as Pasture as % of Land in Farms	4.0	5.6
Cropland Not Harvested or Pastured as % of Land in Farms	7.9	5.4
Total Cropland as % of Land in Farms	85.3	78.1
Woodland Pastured as % of Land in Farms	3.5	3.1
Woodland Not Pastured as % of Land in Farms	3.5	6.1
Permanent Pasture as % of Land in Farms	2.6	4.2
Total Woodland and Permanent Pasture as % of Land in Farms	9.6	13.4
Average Farm Size--Acres	236.5	200.3

12. United States Department of Commerce, *United States Census of Agriculture 1964*, Bureau of the Census, Washington, D.C., 1966.

However, other factors of the agricultural systems in the Illinois study area indicate the contrast which apparently exists.

The boundary between the contrasting adjacent soil regions in Ohio also divides both Clinton and Warren Counties. As a result, county land use data do not reflect the contrast between the soil regions. Land use by soil type for Clinton County (see Table 11) does indicate the apparent relationship of more intensive use, hence a greater percentage of land devoted to cropland, on the younger Wisconsin age soils. A greater percentage of forest and permanent pasture on the Illinoian age soils appears to support the principle of underuse. The implied relationships of soils and land use in the two soil regions appears even more evident if the percentage of idle and miscellaneous land uses are compared in addition to the forest and permanent pasture percentages.

Crops

Topography, climate, and soil can each limit the kinds of crops successfully grown in an area.[13] Within the restrictions of a level to gently rolling landscape, soil characteristics are the determining cause

13. Ross and Case, *op. cit.*, p. 16.

Table 11. Agricultural Land Use by Soil Type, Clinton County, Ohio--1961[14]

	% Crop-land	% Perm. Past.	% Wooded	% Perm. Past. and Wooded	% Idle	% Misc.
Illinoian Age						
Avonburg	84.0	5.2	6.1	11.3	1.4	3.3
Clermont	80.9	2.4	14.4	16.8	0.9	1.4
Wisconsin Age						
Brookston	93.7	3.0	2.8	5.8	0.1	0.4
Fincastle	90.8	3.6	2.9	6.5	0.1	2.6
Ragsdale	94.6	1.4	3.2	4.6	0.0	0.8
Reesville	88.6	3.0	5.8	8.8	0.1	2.5

14. United States Department of Agriculture, Soil Survey, Clinton County, Ohio, Soil Conservation Service, Series 1958, no. 23, 1962, pp. 20-21.

of any crop dissimilarities noted in the study areas because in small, adjacent regions climate is essentially the same.[15] The productive capacity of soils under a given climate is due to the suitability of the soils as rooting mediums and to the ability of horizons penetrated by roots to store water and nutrients in forms available to growing crops.

Fundamental to any farming type, and thus to any agricultural system, are the kinds and qualities of crops which can be grown advantageously. An understanding of soil factors influencing the production of these crops is basic to the appreciation of the cropping possibilities in any area.[16] On better suited soils, the choice of rotations and cropping systems are among many. As the soil has poorer physical properties or another feature becomes less desirable, the number of systems from which to choose are fewer.[17] The variations between the adjacent regions of each study area in drainage capabilities, in amounts of available plant nutrients, and in the capability of root development seem to result in variations in the amount of cropland

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15. G.D. Hubbard, "A Case of Geographic Influence Upon Human Affairs," Bulletin of the American Geographical Society of New York, vol. 36 (1904) pp. 145-157.

16. McNall and Roth, op. cit., p. 1.

17. W.H. Allaway, "Cropping Systems and Soil," Soil, Yearbook of Agriculture, 1957, United States Department of Agriculture, Washington, D.C., pp. 386-395.

devoted to specific crops. Corn and soybeans appear to be affected more than other crops.

There is a close visual relationship between the corn belt and the extent of Wisconsin age glaciation in southwest Ohio, southeast Indiana, and east-central Illinois.[18] This visual relationship may indicate a close correlation between soils and the importance of corn in the agricultural systems. Ross and Case[19] point out a distinct relationship between corn acreage and the character of the soil in Illinois. In Coles County, corn is the chief cash crop and is relatively unaffected by competition between other crops for acreage.[20] Coles County is well adapted to the use of large machinery because of the near-level topography and relatively large fields; corn production is associated with both large fields and large machinery.[21] In Jasper County, soybeans outrank corn as the number one crop. The percent of harvested cropland devoted to corn in Coles County (46.7%) appears to be significantly greater than the percent of harvested cropland devoted to corn in Jasper County (27.5%) as calculated from the

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18. See the maps in John K. Rose, "Corn Yields and Climate in the Corn Belt," Geographical Review, vol. 26 (1936) pp. 88-102.

19. Ross and Case, op. cit., p. 71.

20. Ibid., p. 46.

21. McNall and Roth, op. cit., p. 2.

1964 Census of Agriculture data.

Corn acreage appears to be dominant on Wisconsin age soils in the Indiana and Ohio study areas as well as in Illinois. The percent of harvested cropland devoted to corn in Decatur County, Indiana (44.0%) seems to be significantly greater than the percent of harvested cropland devoted to corn in Ripley County, Indiana (27.6%) from the 1964 Census of Agriculture data. The relationship is further supported by the percent of cropland used for corn on the major soil types of the Indiana study area: Fincastle (32%), Brookston (39%), and Clermont (23%).[22] In Ohio, percentage figures for various crop rotation systems, especially those rotations which include two years of corn, a short rotation (three years) with corn or continuous corn, seem to indicate more land devoted to corn on the Wisconsin age soils (see Table 12.)

Soybeans grow well on soils too acid for alfalfa or clover. This crop has been adapted to poorer soils as a relatively profitable grain crop. The soybeans can be planted later in the spring than corn and harvested earlier in the fall which helps to spread out the field work on crops.[23] The later planting can help to overcome the spring wetness handicap on the "planosolic"

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22. Bushnell, op. cit., p. 43.
23. Ross and Case, op. cit., p. 71.

Table 12. Crop Rotation Systems by Soil Type in Ohio[24]

	Brookston-Ragsdale	Fincastle-Reesville	Clermont-Avonburg
Continuous Corn	5%	4%	2%
Corn-Small Grain-Meadow	34	35	21
Corn-Corn-Sm.Gr.-Meadow	22	20	6
Corn-Corn-Sm.Gr.-Mead.-Mead.	9	8	4
Corn-Sm.Gr.-Mead.-Mead.	14	16	28
Corn-Soybean-Sm.Gr.-Mead.	3	4	14
Corn-Sm.Gr.-Mead.-Mead.-Mead.	0	3	4
Permanent Pasture	6	7	8
Long Time Meadow	3	3	9

24. J.B. Jones, H.J. Mederski, and O.L. Musgrave, Crops and Cropping Sequences as Related to Soil Types, Ohio Agricultural Experiment Station Research Bulletin 919, 1962.

soils. Soybean plants also have greater resistance to mid and late summer moisture deficiencies of the "planosolic" soils than does corn.[25] A greater percentage of cropland acreage devoted to soybeans on the Illinoian age soils of the study areas than on the Wisconsin age soils is the anticipated relationship. In Illinois, soybeans compete with wheat, oats, and hay for acreage on the fertile soils of Coles County under a cash grain farming type.[26] However, with farming on a smaller scale in Jasper County than in Coles County, much variation can occur in farm income. Soybeans have gained strength relative to corn because of the better adaptation to climatic hazards and the greater likelihood of reasonable returns from soybeans than from corn. Soybean acreage has increased in Jasper County in more recent years as a means of stabilizing farm income.[27] The percent of harvested cropland devoted to soybeans in Jasper County (45.7%) seems to be significantly greater than the percent of harvested cropland devoted to soybeans in Coles County (33.5%) as calculated from the 1964 Census of Agriculture data. The implied rela-

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25. J.C. Weaver, "Changing Patterns of Cropland Use in the Middle West," Economic Geography, vol. 30 (1954) pp. 44-47.

26. Ross and Case, op. cit., p. 46.

27. Weaver, op. cit., p. 46.

tionship between greater soybean acreage and the more acid "planosolic" soils is further supported by the Census data from Indiana; Ripley County has 28.3% of its harvested cropland in soybeans compared to 17.8% for Decatur County.

Yields and Fertilizers

The yield of a crop on a given site results from a combination of soil characteristics, management, and weather conditions.[28] The conditions of temperature and precipitation are essentially uniform in each study area, making soil variations and management practices primary forces affecting crop yields. It generally has been assumed that soils differing in genesis, morphology, or associated characteristics probably differ in yield levels.[29] In fact, according to Avery,[30] investigations leave little room for doubt that yields of grain and root crops are significantly affected by soil type variations. However, resultant yields are complicated by the fact that the soil nutrient status, pH, amount and distribution of organic matter, and structure are influenced by past land use and management. Various technical improvements, especially increased use of fertilizers,

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28. B.W. Avery, "Soil Type and Crop Performance," Soils and Fertilizers, vol. 25 (1962) p. 341.
29. D.A. Rennie and J.S. Clayton, "The Significance of Local Soil Types to Soil Fertility Studies," Canadian Journal of Soil Science, vol. 40 (1960) p. 146.
30. Avery, op. cit., p. 343.

have raised crop yields, tending to reduce the natural productivity differences between regions; but major soil characteristics are still important factors in crop production levels.[31]

Yield estimates have been made for the important soil series in the study areas (see Tables 13 and 14.) The estimates for the Wisconsin age soils seem to indicate that higher average crop yields are found on these soils in the study areas than on the older Illinoian age soils. Corn yields are especially affected by soil differences. The highest yields are on the younger soils high in humus and nitrogen. On the older soils corn needs heavy fertilization to produce enough for feed. Corn uses large amounts of nitrogen and demands a high level of fertility. In the corn belt, total soil nitrogen represents a convenient numerical index of soil productivity. Yields of corn under similar climatic conditions vary accordingly.[32] This relationship suggests higher corn yields on the younger soils than on the older soils in each study area. Average corn yields from Illinois (Coles County 84.1 and Jasper County 53.5) and from Indiana (Decatur County 74.5 and Ripley County 68.3), as calculated from 1964 Census data, tend to support the relationship.

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31. Bushnell, op. cit., p. 39.

32. Hans Jenny, Factors of Soil Formation, McGraw-Hill, New York, 1942, p. 16.

Table 13. Estimated Crop Yields for Major Soil Series in Illinois Study Area--Average (A) and High (H) Levels of Management[33]

	Corn		Soybeans		Wheat		Oats	
	A	H	A	H	A	H	A	H
Flanagan	89	134	32	46	30	53	57	75
Drummer	90	141	31	47	32	58	60	84
Cisne	55	100	18	32	20	45	39	53
Hoyleton	55	101	17	31	20	46	--	--

33. R.T. Odell and W.R. Oschwald, Productivity of Illinois Soils, University of Illinois Cooperative Extension Service, Circular 1016, 1970.

Table 14. Estimated Crop Yields for Major Soil Series in Ohio and Indiana Study Areas--Average (A) and High (H) Levels of Management[34]

	Corn		Soybeans		Wheat		Oats	
	A	H	A	H	A	H	A	H
Fincastle	70	105	26	38	26	38	40	72
Brookston	85	120	28	42	30	50	50	84
Reesville	75	110	26	40	28	40	44	74
Ragsdale	85	120	28	42	36	50	50	84
Clermont	50	85	18	28	18	30	26	60
Avonburg	55	90	20	28	20	34	34	70

34. S.W. Bone, G.E. Bernath, G.K. Dotson, H.J. Mederski, and R.L. Meeker, Productivity Guide for Ohio Soils, The Ohio State University Cooperative Extension Service, Bulletin 476, 1966.

Grain production, especially soybeans, has increased rapidly in the recent past on the "planosolic" soil areas. Level land permits the use of large machinery for crop production. The response to fertilizer treatment has been adequate. Grain production on the "planosolic" soils can be increased by planting more acreage to grain and by applying more fertilizer to the areas now in grain.[35] However, despite increased use of fertilizer, expected soybean, wheat, and oat yields seem to be lower on the "planosolic" soils than on the Wisconsin age soils in the study areas (see Tables 13 and 14.) Average soybean, wheat, and oat yields, calculated from the 1964 Census data for the study area counties in Illinois and Indiana, indicate the apparent difference in yield levels (see Table 15.)

Crop yield data has little meaning without looking at the management practices needed to obtain the yields considered.[36] Yields vary as in Tables 13 and 14 between average and high management levels. High level managment means harvesting crops with only minimum losses.[37] Adequate applications of needed plant nutri-

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35. C.P. Schumaier, Marketing Southern Illinois Corn, Wheat, Soybeans: A Report of Research, University of Illinois Agricultural Experiment Station Bulletin 595, 1955.

36. University of Illinois, Productivity of the Soils of the North Central Region of the United States, North Central Regional Research Publication 166, 1965, p. 6.

37. Ibid, p. 7.

Table 15. Soybean, Wheat, and Oat Yields for the Study Area Counties in Illinois and Indiana--1964

	Soybeans	Wheat	Oats
Decatur	25.7	32.5	37.7
Ripley	23.1	28.4	33.4
Coles	23.4	39.4	50.7
Jasper	17.9	36.8	36.5

ents raise potassium and phosphorus content of soils to optimum levels and maintain them there. Good physical condition of the soil and adequate drainage are maintained and weeds, plant diseases, and insects are controlled. Crop residues are used efficiently and improved and adapted crop varieties have been introduced. Harvest costs are reduced by proper procedures for each crop. The production level is about ninety percent of that of the long term average yields on experimental plots. It is a level within reach of all farmers, but reached by only about ten percent on a continuous basis. Conditions of cultivation which apply to experimental plots cannot be expected to furnish as a guide to yields even on farms with varying soil types in the same county.[38]

38. H.D. Vigor, "Crop Estimates in England," *Journal of the Royal Statistical Society*, vol. 91 (1928) p. 11.

Yields of the average management level are a better guide for agricultural land evaluation than yields with high level management which often depend on a better farm manager.[39] Average level management implies that lime and fertilizer often are inadequate or not properly balanced for optimum yields. Some erosion controls and drainage improvements have been made, but often more are needed. The cropping system, plant population per acre, organic matter supply, and soil physical condition are below the level for optimum yields. Tillage methods, use of adapted seeds, and use of weed, disease, and insect controls may not be adequate. It can be noted that as the frequency of row crops increases, the management level must improve to obtain similar yield levels.

It is assumed that the average yield for each crop in each region of the study areas will be a figure somewhere between the average level management and high level management yield estimate. The randomly selected group of farms in each region is supposed to represent a cross-section of farms managed by good, average, or poor operators.

With improved fertilizer programs, the advantage of farmers on good soils has decreased relative to that

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39. University of Illinois, op. cit., p. 6.

of farmers on poorer soils.[40] Changes in the fertilizer program in Illinois have had a greater effect on Cisne soils than on Flanagan soils. The yield differences are less pronounced than before the increased use of fertilizer on the "planosolic" soils. Jordan and Baker[41] feel the geographic boundaries between soil regions are less distinct as a result. It is recognized that Cisne soils are low in potassium. Crops respond very well to potash, so an increased application per acre is underway to reduce the potassium deficiency. The need for lime closely relates to soil acidity and plant nutrient requirements. A high degree of acidity or low soil pH may be directly unfavorable to plant growth and may reduce the amount of plant food available, especially phosphorus.[42] A continued program of soil testing and application of nutrients according to plant needs can greatly increase the yield potential on the "planosolic" soils. The fertilizer program must be adequate enough to resupply those nutrients removed by crops, if yields are to be maintained or improved. The pounds of nutrients removed per acre with the harvested crop are substantial (see Table 16.) It appears that yields per

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40. M.F. Jordan and C.B. Baker, Effects of Fertilizer Programs on the Economic Choice of Crops in Selected Areas of Illinois, University of Illinois Agricultural Experiment Station Bulletin 683, 1962, p. 33.

41. Ibid.

42. Bushnell, op. cit., p. 38.

pounds of fertilizer per acre are noticeably higher on the more fertilie, younger soils of the study areas than on the older "planosolic" soils.

Table 16. Pounds of Nutrients Removed with Harvest, Per Acre[43]

	N	P	K
Corn--100 bushel yield	148	23	71
Oats--100 bushel yield	97	16	68
Wheat--50 bushel yield	96	16	48

In addition to the average yield level, the variability of yields over a period of years can be a useful measure of the relative capability of two soil regions. Yield dependability might well be taken into account along with average production figures when appraising land for tax purposes.[44] In Illinois for example, yields are higher and variability is lower in Coles County than in Jasper County, making Coles County a potentially more valuable agricultural region (see Table 17.)

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43. Cyril Hopkins and James Pettit, The Fertility of Illinoian Soils, University of Illinois Agricultural Experiment Station Bulletin 123, 1908, p. 188.

44. E.R. Swanson, Variability of Yields and Income from Major Illinois Crops, 1927-1953, University of Illinois Agricultural Experiment Station Bulletin 610, 1957, p. 3.

Table 17. Average Crop Yields and Variability in Yield, Coles and Jasper Counties, Illinois--1927 to 1953[45]

	COLES		JASPER	
	average yield bu/A	variability	average yield bu/A	variability
Corn	42.9	16.3%	31.4	16.6%
Soybeans	20.1	9.8	12.9	12.4
Wheat	32.1	24.1	20.0	32.5
Oats	19.9	13.4	14.5	20.4

Land Values

The wide variation in the crop-producing power of soils is a recognized fact of agriculture. This variation can be reflected in the range of values of land per acre. The best land in an area can be worth thirty times more than the poorest in terms of assessed value for tax purposes.[46] Ottoson[47] supports the notion that soil productivity differences are the main reason for differences in land values. He argues that buyers are

45. *Ibid.*

46. United States Department of Agriculture, *Soil Survey of Decatur County, Indiana*, Bureau of Soils, 1922, p. 7.

47. H.W. Ottoson et al., *Valuation of Farm Land for Tax Assessment*, Nebraska Agricultural Experiment Station Bulletin 427, 1954, p. 9.

willing to bid more for land offering a greater possible return in crop yields. While evidence seems to indicate land value per acre and agricultural productivity varying together, land values increase rapidly with higher grade soils.[48]

In Illinois, land value remains the lowest in the southern part of the state in the "planosolic" soil region because of the naturally low productivity and the large areas in pasture or timber. Value of land per acre ranges from $75 to $125 in Jasper County. Average value of farms, including land and buildings, ranges from $10,000 to $19,900. In contrast, value of land per acre ranges from $175 to $225 in Coles County. Average values of farms, including land and buildings, varies from $30,000 to $39,900.[49] Earlier values for land per acre, cited by Hubbard,[50] support the relationship between higher land values and better soils. Coles County assessed values ranged from $75 to $125 per acre in the early 1900s compared to $15 to $40 per acre for Cumberland County ("planosolic" soil region.)

The relationship of land values and crop productivity of soils is further substantiated by data from

48. Bushnell, op. cit., p. 98.
49. Ross and Case, op. cit., p. 22.
50. G.D. Hubbard, op. cit., p. 152.

the 1964 Census of Agriculture. The average value per acre of land and buildings in Decatur County, Indiana, is $306.27 while the average value in Ripley County, Indiana, is only $176.90. The average value per acre of land and buildings in Coles County, Illinois, is $427.92 compared to an average value of only $237.79 in Jasper County, Illinois.[51]

Tenancy and Operator's Age

The tenure system in agriculture is a complex cycle of renting land from the owner, giving up rented land, and renting out land owned. Wills and Koeller[52] aptly describe such a cycle in southern Illinois. Most farmers own their land and home. In the active years of life these operators rent more land than they own and occasionally buy more land. A high proportion, higher than elsewhere in Illinois, are part-owners. Toward the retirement years, the operator farms less and less land, first giving up renting land from others, and then renting out part of his own land. Finally, the operator retires in his home on the farm and rents out land for income in his old age. This tenure pattern is associated with low farm incomes, low land values, and

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51. United States Department of Commerce, *op. cit.*

52. J.E. Wills and H.L. Koeller, *Employment and Income of Rural Families in Southern Illinois*, University of Illinois Agricultural Experiment Station Bulletin 580, 1954, p. 23.

low capital inputs per farm. It is complex because of the many multiple tract farms which are inconvenient to operate. Renting fields on a year to year basis discourages good practices of land use and maintenance of soil fertility.

Ross and Case[53] view the land tenure system somewhat differently than do Wills and Koeller. The characteristic differences in agricultural systems can be closely related to land tenure. The largest percentage of rented land is found in areas of high productivity and of high proportions of tillable land. Such land is best suited to grain production, so grain farming and tenancy go well together. Such areas require large amounts of capital for ownership. It may be that farm operators not able to secure the capital to buy a farm, but desiring to farm a productive area, become farm tenants, renting all the land they operate from someone else.

Data from the 1964 Census of Agriculture support the apparent relationship in Illinois between the "planosolic" soils and a higher percent of part-owners; Jasper County has 49.4% part-owners compared to 33.1% in Coles County. The implied relationship between more

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53. Ross and Case, _op_. _cit_., p. 19.

productive soils and a higher percentage of farm tenants is upheld by Census data in both Indiana and Illinois. Farm tenants comprise 18.6% of the number of farm operators in Decatur County, Indiana, compared to 7.5% in Ripley County and tenants comprise 28.5% of the number of farm operators in Coles County, Illinois, compared to 9.8% in Jasper County.[54]

The operator's age may relate to the productivity of a farm. Sitterley[55] reasons that there are more older operators in the less productive soil regions than in the more productive soil regions of an area because the older operators may be more interested in reducing their work load than in improving production. These older men have limited management skills and little interest in change or in investment in long range improvements, according to Hart.[56] The statements of Hart and Sitterley imply a relationship in the study areas between older farm operators and the "planosolic" soils and younger farm operators and the younger Wisconsin age soils. However, the relationship is not supported by data from the 1964 Census of Agriculture,

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54. United States Department of Commerce, op. cit.

55. J.H. Sitterley, "Some Factors Affecting the Rate of Retirement of Farms in the Submarginal Land Area of Ohio," Journal of Farm Economics, vol. 26 (1944) pp. 737-753.

56. Hart, op. cit.

and must be investigated further in this thesis. The average age of farm operators in Decatur County, Indiana, is 51.5 years while the average age is 52.6 years in Ripley County. The average age of farm operators in Coles County, Illinois, is 50.4 years compared to 50.6 years in Jasper County.[57]

It becomes a matter of examining each of the suggested relationships between soils and the factors of the agricultural systems discussed above in this chapter. The sample groups of farms, discussed in Chapter One of this thesis under "Methods and Anticipated Results," are used to verify the significance of the relationship of each of the mentioned factors in each of the three study areas.

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57. United States Department of Commerce, op. cit.

CHAPTER IV. AN ANALYSIS OF THE AGRICULTURAL SYSTEMS IN THE THREE STUDY AREAS

A number of relationships were suggested in the preceeding chapter as being evidence of the influence of the contrasting adjacent soil regions on the agricultural systems in each study area. The number of factors which must be examined to determine their role in the apparent contrast in agricultural systems necessitates the use of statistical analysis of the data compiled for the sample group of farms in each study area. Each of the implied relationships are examined subsequently using either an analysis of variance test[1] or a Chi-square test. All tests are set to reject the null hypothesis--that there is no significant difference between the adjacent soil regions in the value of each of the variables--at the .01 level of significance. Data for each of the three study areas are analyzed and presented for all of the variables (see Tables 18 and 19.)

It must be stated here that this study has a temporal limit. The significance or lack of significance of any of the variables is applicable only to the time

1. The analysis of variance test used in the analysis of data in this thesis was the Michigan State University, Agricultural Experiment Station, STAT Series no. 13, One Way Analysis of Variance.

Table 18. Level of Significance of Variables Analyzed Using Analysis of Variance Test

	Illinois	Indiana	Ohio	Significance[1]
Storie Index	<0.0005	<0.0005	<0.0005	***
Salter Balance	.394	.003	<0.0005	**
Acreage in Farm	.281	.044	.078	
Total Labor	.158	.135	.885	
Family Labor	.064	.763	.083	
Months of Work	.743	.051	.474	
Operator's Age	.093	.074	.809	
Value per Acre	<0.0005	<0.0005	<0.0005	***
Livestock Units	.085	.002	.063	*
Corn Yield	<0.0005	.006	.040	**
N on Corn	.213	.743	.920	
P on Corn	.162	.314	.026	
K on Corn	.900	.577	.403	
Total Corn Fert.	.343	.454	.299	
Soybean Yield	<0.0005	.710	.685	*
N on Beans	.322	.868	.010	*
P on Beans	.001	.035	<0.0005	**
K on Beans	<0.0005	.034	<0.0005	**
Total Bean Fert.	<0.0005	.034	<0.0005	**
Wheat Yield	.009	.299	.408	*
N on Wheat	.001	.347	.214	*
P on Wheat	.003	.155	.338	*
K on Wheat	.385	.161	.147	
Total Wheat Fert.	.010	.147	.155	*
% Farm Cropland	.001	<0.0005	.010	***
% Cropland Crops	.349	.497	.103	
% Cropland Pasture	.690	.071	.304	
% Non-cropland Past.	.508	.384	.240	
% Farm not-Tilled	.092	.955	.744	
% Farm Idle	.145	.062	.777	
% Farm Woodlot	.002	<0.0005	.002	***
% Woodlot Pasture	.459	.235	.326	
% Farm Diverted	.174	.883	.790	
% Cropland Corn	.003	<0.0005	<0.0005	***
% Cropland Soybeans	.065	.001	<0.0005	**
% Cropland Wheat	.007	.702	.504	*
% Cropland Hay	.036	.512	.517	

[1] One * means significance at .01 level in one area; two * means significance in two areas; three * means significance in three areas.

Table 19. Values for Chi-square Test and Significance of Variables Analyzed Using Chi-square Test

	Illinois	Indiana	Ohio	Chi-square value for significance[1]
Presence of Artificial Drainage	2.08	3.19	2.80	≥6.64
Type of Artificial Drainage	50.00*	42.59*	46.15*	≥9.21
Change in Farm Size 1966-1970	0.53	1.02	1.09	≥9.21
Change in Cropland Size 1966-1970	1.37	1.02	4.95	≥9.21
Full-Time Hired Hand	2.38	3.52	5.56	≥6.64
Farm Ownership	7.72	4.65	1.48	≥9.21

* = significant value

[1] test made at .01 level of significance

period (1968 to 1970) delimited by the data collected. However, the same set of variables may be useful to other studies set in a similar framework.

The contrast in soil capabilities between regions in each of the three study areas seems to be clearly indicated by the significant difference in the values of the Storie Index (see Table 20.) These values seem to verify the difference in natural fertility and productive capacity between soil regions.

The percentages of farms in the study groups employing artificial drainage give evidence of the relatively poor natural drainage in both soil regions in each of the study areas. The Wisconsin age soil region has artificial drainage on 100% of the study farms in the three areas. The Illinoian age soil regions of Illinois and Ohio have artificial drainage on 92% of the study farms and this soil region of Indiana has artificial drainage on 88% of the farms. However, in each of the study areas, there is a significant difference in the type of drainage installed in the two soil regions as indicated by the Chi-square test (see Table 19.) In the Wisconsin age soil region of each study area, all of the farm operators use tile drains. In the Illinoian age soil region of each study area, nearly all of the farm operators use open ditch drains (see Table 21.) The significant variation in drainage meth-

Table 20. Storie Index Values for Soil Regions in the Study Areas

	Illinoian	Wisconsin
Illinois	31.96	57.48
Indiana	34.72	61.48
Ohio	33.88	55.48

Table 21. Type of Artificial Drainage in Study Areas, by Soil Regions

	Illinois	Indiana	Ohio
Wisconsin			
Tile drains	100%	100%	100%
Illinoian			
Ditch drains	92%	80%	88%
Tile drains	0%	8%	4%
No drains	8%	12%	8%

ods appears to emphasize the claypan obstruction to drainage on the Illinoian age "planosolic" soils.

The average farm size in the soil regions of Illinois and Indiana is considerably larger than Census of Agriculture data indicates (see Table 22.) The larger size can possibly be explained by the exclusion of part-time farmers from this study and thus the elimination of small non-commercial farms which are included in the Census averages. Even though the farms seem to be larger on the average in the Wisconsin age soil regions of Illinois and Indiana than in the respective Illinoian age soil regions, the difference is not significant for the sample group of farms in this study. In Ohio, the average farm size in the two soil regions is not significantly different for the sample group of farms, despite the apparent larger size in the Illinoian age soil region than in the Wisconsin age soil region (see Table 18.)

Land Use

The relationship between soil regions in each of the three study areas and allocation of land use may be stated as follows: a significantly greater percentage of farmland is devoted to cropland use on the Wisconsin age soils than on the Illinoian age soils. Further, a significantly greater percentage of each farm is in woodlots on the Illinoian age soils than on the Wiscon-

Table 22. Land Use Allocation for Study Areas, by Soil Regions

	Illinois		Indiana		Ohio	
	Ill.	Wis.	Ill.	Wis.	Ill.	Wis.
Total Cropland as % of Farm ***	88.3%	95.0%	76.5%	88.3%	78.6%	87.4%
Cropland Harvested as % of Cropland	89.3	86.7	83.3	80.4	75.1	82.6
Cropland Pastured as % of Cropland	1.1	0.8	6.5	11.4	12.6	8.8
Noncropland Pastured as % of Farm	2.4	1.8	6.0	4.2	9.0	5.2
Land Not Tilled as % of Farm *	7.9	11.6	7.7	7.6	8.4	7.7
Idle Land as % of Farm	3.9	2.7	4.2	2.5	3.5	3.9
Woodlots as % of Farm***	6.3	0.9	13.6	5.1	9.4	3.4
% of Woodlot Pastured	4.8	1.6	16.8	30.3	12.3	21.9
Diverted Land as % of Farm *	7.5	10.5	7.9	7.6	8.3	7.7
Average Farm Size						
Study Group (Acres)	475.3	544.1	292.4	396.8	422.7	329.2
Census Data (Acres)	200.3	236.5	117.4	174.3	-----	-----

* The majority of land not tilled is also land in the federal government diverted-acres programs.

*** Significant difference between soil regions in all three study areas.

sin age soils. Analysis of variance tests of the other uses of farm land indicate there apparently is no significant difference between the adjacent soil regions in the percentage of cropland in crops, the percentage of cropland in pasture, the percentage of non-cropland in pasture, the percentage of farmland not tilled, the percentage of farmland idle, the percentage of woodland used for pasture, and the percentage of farmland in government diverted acres programs (see Tables 18 and 22.)

The analysis of land use allocation in the adjacent soil regions of each of the three study areas appears to show a more complete utilization of land for agricultural production on the Wisconsin age soils and a less complete utilization of land for agricultural production on the Illinoian age soils. The significant difference in percentage of land devoted to crops between the adjacent regions (see Tables 18 and 22) suggests a more intensive use of land on the Wisconsin age soils than on the Illinoian age soils. The relatively less intensive land use on the Illinoian age soils suggests that the underuse principle of Hart[2] may be applied to these soil regions. The "planosolic" soils may be in the initial stages of underuse, preceeding land abandonment.

The significant difference in the percentage of land in woodlots (see Tables 18 and 22) may reflect the

2. Hart, _op. cit._

variation in soil productivity between the adjacent soil regions. In Indiana and Ohio, it might be true that less land has been cleared for cropland on the older soils because of their relatively low productivity. Further, this relationship seems to support the findings of Bushnell[3] that the "planosolic" soils tend to retain more forest cover because of the problems of drainage. A greater percentage of land remaining in woodlots or reverting to forest cover tends to signal an underuse of land for agricultural production. The significant difference in the percentage of land in woodlots in Illinois may be a reflection of the relative ages of the two soil regions. Trees have had a longer time period in which to encroach upon soil areas, classified as grassland soils because of their morphology, in the Illinoian age region than in the Wisconsin age region.

Changes in farm size and changes in cropland size over the past three years (1968-1970) were analyzed using the Chi-square test. No significant difference was found between the soil regions for either of these factors (see Table 19.) A great majority of farms maintained the same total acreage and same cropland acreage over the period in question (see Table 23.)

3. Bushnell, op. cit. p. 43.

Table 23. Percentage of Farms Maintaining Farm Size and Cropland Size 1968-1970, by Soil Region

	Maintained Farm Size	Maintained Cropland Size
Illinois		
Illinoian soils	84%	72%
Wisconsin soils	84	84
Indiana		
Illinoian soils	80	80
Wisconsin soils	84	84
Ohio		
Illinoian soils	88	76
Wisconsin soils	96	92

<u>Corn</u>

The relationships between the soil regions in the study areas and corn production are as follows: a significantly greater percentage of cropland is devoted to corn in the Wisconsin age soil regions than in the Illinoian age soil regions in the three study areas; and corn yields per acre in the Wisconsin age soil regions are significantly higher than in the Illinoian age soil regions of Illinois and Indiana. There is not a significant variation between regions for corn yield in Ohio. The amounts of fertilizer applied to corn acreage--nitrogen, phosphorus, potassium, and total fertilizer--apparently are not significantly different between adjacent soil regions (see Table 18.)

The percentage of cropland planted to corn in the Wisconsin age soil regions of Ohio and Indiana seemingly shows the importance of corn, in a corn-livestock farming type, as suggested by previous farm type classifications.[4] In Illinois, the percentage of cropland planted to corn in the Wisconsin age soil region seems to show the importance of corn, in a cash-grain farming type, as suggested in previous studies.[5] Corn ranks as the first crop in each of the younger soil regions (see Tables 24 and 25.) The significantly smaller percentage of cropland planted to corn in each of the Illinoian age soil regions appears to indicate a lesser importance for corn in a more mixed farming type in the older soil regions, as previously described by Bushnell[6] and Ross and Case.[7] Corn ranks as the first crop on the Illinoian age soils in Indiana and as the second crop on these older soils in Illinois and Ohio (see Tables 24 and 25.)

The significantly higher corn yield on the Wisconsin age soils than on the Illinoian age soils in Illinois and Indiana seems to indicate: first, the generally higher fertility level of the younger soils; second, the greater importance of corn in the cropping

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4. Bushnell, _op. cit._
5. Ross and Case, _op. cit._
6. Bushnell, _op. cit._
7. Ross and Case, _op. cit._

Table 24. Agricultural Activity Values and Percentage of Agricultural Activity Contributed by the Two Primary Activities in the Study Areas, by Soil Region

	Value*	%
Illinois		
Illinoian soil region		
Soybeans	202.4	43.6 (Livestock 12.2%)
Corn	157.5	33.8
Total		77.4
Wisconsin soil region		
Corn	224.6	51.7 (Livestock 2.9%)
Soybeans	169.6	39.1
Total		90.8
Indiana		
Illinoian soil region		
Corn	198.9	44.5 (Livestock 12.2%)
Soybeans	132.4	29.6
Total		74.1
Wisconsin soil region		
Corn	296.6	49.7 (Soybeans 8.7%)
Livestock	186.5	31.3
Total		81.0
Ohio		
Illinoian soil region		
Soybeans	225.2	51.5 (Livestock 8.8%)
Corn	122.0	27.9
Total		79.4
Wisconsin soil region		
Corn	279.5	55.8 (Soybeans 13.8%)
Livestock	87.9	17.6
Total		73.4

* Value is the weighted number assigned to each agricultural activity, according to man-days per acre of crops and livestock units for animals on each farm in each soil region.

Table 25. Percentage of Cropland Devoted to Individual Crops and Average Livestock Numbers in Study Areas, by Soil Regions

		Illinois	Indiana	Ohio
Corn	Illinoian Soil Region	35.0%	44.2%	27.1%
	Wisconsin Soil Region	49.9	65.9	62.1
Soybeans	Illinoian Soil Region	50.6	33.1	56.3
	Wisconsin Soil Region	42.4	13.0	17.3
Wheat and Oats	Illinoian Soil Region	13.2	13.5	13.0
	Wisconsin Soil Region	7.8	14.6	15.3
Hay	Illinoian Soil Region	0.9	6.9	3.3
	Wisconsin Soil Region	0.0	5.3	5.2
Livestock Units*	Illinoian Soil Region	56.8 units	54.4 units	38.4 units
	Wisconsin Soil Region	12.5	186.5	87.9

* Livestock units are calculated based on feed consumption; one cow or one horse equals one unit, one calf equals one-half unit, etc.

system on the younger soils; and third, either an optimum use of fertilizer on the younger soils or a relatively deficient use of fertilizer on the older soils. Since the differences in fertilizer application rates between the adjacent regions are not significant for any of the three nutrients (see Tables 18 and 26), it appears that a less than optimum rate of fertilizer has been applied on the older soils, especially nitrogen. Corn uses large amounts of nitrogen, and it seems that the amount applied is less than adequate for soils relatively low in natural productivity, as the "planosolic" soils. Although the corn yields are not significantly different between the two soil regions in Ohio, it appears that higher yields could be achieved on the younger soils than on the older soils of the area. Several factors may be responsible for the lack of significant variation in yield: the level of management in the two soil regions, the variety of corn seed used by the individual farm operators, and the timing of planting and fertilizing operations in the two soil regions. None of these factors were measured in this study, but considering the significant variation in natural productivity between the adjacent regions, one would expect a significant yield difference.

Table 26. Crop Yields and Fertilizer Application Rates for the Three Study Areas, by Soil Regions

	Illinois		Indiana		Ohio	
	Ill.	Wis.	Ill.	Wis.	Ill.	Wis.
Corn bu/A	87.8	134.5	112.8	134.0	91.1	109.9
N on Corn lbs/A	121.3	142.4	147.2	142.5	121.6	123.4
P on Corn	81.6	102.6	103.2	86.5	86.1	60.3
K on Corn	122.2	119.6	113.4	103.5	104.8	87.6
Total on Corn	325.1	364.6	363.8	332.5	312.4	271.2
Soybeans bu/A	32.9	45.1	37.2	43.1	36.0	38.9
N on Beans lbs/A	0.0	0.0	5.5	5.2	8.4	3.2
P on Beans	20.4	0.0	34.4	18.9	39.5	11.4
K on Beans	60.4	0.0	46.0	24.6	63.3	11.4
Total on Beans	80.9	0.0	85.9	48.7	111.2	26.9
Wheat bu/A	41.3	52.6	40.7	45.5	42.4	44.3
N on Wheat lbs/A	42.4	13.6	44.2	34.6	34.2	21.9
P on Wheat	57.0	25.9	50.5	38.9	42.8	34.8
K on Wheat	37.0	25.6	48.4	37.3	47.4	31.6
Total on Wheat	136.5	65.1	143.1	110.7	124.5	88.3

Soybeans

The relationships between the adjacent soil regions in the study areas and soybean production are as follows: a significantly greater percentage of cropland is devoted to soybeans in the Illinoian age soil regions than in the Wisconsin age soil regions of Indiana and Ohio; application rates of phosphorus, potassium, and total fertilizers are significantly higher on the older soils than on the younger soils in Illinois and Ohio; the application rate of nitrogen is significantly higher on the older soils than on the younger soils in Ohio; and the soybean yield is significantly higher on the Wisconsin age soils than on the Illinoian age soils in Illinois (see Table 18.)

The significantly greater percentage of cropland planted to soybeans on the older soils than on the younger soils in Indiana and Ohio tends to indicate the relatively greater importance of soybeans in the mixed farming type on the Illinoian age soils. The significantly lower percentage of cropland planted to soybeans on the younger soils in Indiana and Ohio appears to substantiate the lesser importance of soybeans in the corn-livestock farming type on the Wisconsin age soils (see Tables 24 and 25.) The percentage of cropland devoted to soybeans on the Illinoian age soils in Illinois seems to confirm the dominance of soybeans in the farming system there, as suggested by Weaver.[8] The percentage of cropland devoted to soybeans on the Wisconsin age soils appears to support the statement that soybeans compete with wheat, oats, and hay under a cash grain farming type in Illinois.[9] Soybeans are the first rank crop on the older soils in Illinois and Ohio and the second rank crop on the older soils in Indiana and on the younger soils in Illinois (see Table 24.)

The significantly greater fertilizer application rates on the Illinoian age soils than on the Wisconsin age soils of Ohio seems to have resulted in soybean yields that are similar to those on the younger soils. The similar yields in the two soil regions, despite significantly different fertilizer application rates (see Table 26), seem to support the contention that much greater amounts of fertilizer are needed on the older soils than on the younger soils to produce similar results in Ohio.

The significantly higher soybean yield on the younger soils than on the older soils in Illinois seems to indicate both the generally higher fertility level of the younger soils, and the ability to produce substantial yields on the Wisconsin age soils with a reliance on

8. Weaver, op. cit.
9. Ross and Case, op. cit.

carryover fertilizers applied to corn the previous year in rotation. The fertilizer carryover is apparent because no fertilizer was applied to soybeans on the sample group of farms in the younger soil region. Despite significantly greater application rates of phosphorus, potassium, and total fertilizers per acre on the older soils (see Table 26), considerably lower yields give evidence of the generally lower fertility level of these older soils and a need for even more fertilizers to improve yields in Illinois.

Wheat and Oats

The relationships between the soil regions in Illinois and wheat and oat production are as follows: a significantly greater percentage of cropland is devoted to wheat and oats on the older soils than on the younger soils; wheat yield per acre is significantly higher on the younger soils than on the older soils; and application rates of nitrogen, phosphorus, and total fertilizers on wheat are significantly greater on the Illinoian age soils than on the Wisconsin age soils. An analysis of the relationships between the soil regions in Indiana and Ohio and wheat and oat production shows that there is no significant difference in yield, in the percentage of cropland planted to wheat and oats, and in fertilizer application rates.

The significantly greater percentage of cropland planted to wheat and oats on the Illinoian age soils compared to the Wisconsin age soils in Illinois seems to support the mixed-farming type classification for the older soil region and the cash grain farming type classification for the younger soil regions (see Table 25.) It appears that wheat and oats have similar levels of importance in the adjacent soil regions of Ohio and Indiana, despite what seem to be different farming-type classifications for the contrasting soil regions. Wheat is the third rank crop in all soil regions of the study areas.

The significantly higher wheat yield on the Wisconsin age soils than on the Illinoian age soils in Illinois appears to further substantiate the generally higher fertility level of the younger soils and a deficient level of fertilizer application on the older soils. Relatively little fertilizer seems to result in excellent yields on the younger soils (see Table 26.) The significantly lower wheat yield on the older soils, despite significantly greater rates of application of nitrogen, phosphorus, and total fertilizers than on the younger soils appears to show the need for improved fertilizer programs for wheat on the "planosolic" soils. While the fertilizer application rates are not significantly different between the adjacent soil regions in

Ohio and Indiana, the somewhat larger amounts of fertilizer applied to the older soils seem to be sufficient to result in yields comparable to the yields on the younger soils (see Table 26.)

Other Agricultural Production Factors

The crop rotation systems in the adjacent soil regions of each study area were evaluated using the values from the Salter Productive Balance (see Table 2, Chapter I.) A significantly greater amount of nutrients are removed from the soil by the rotations employed on the Wisconsin age soils than on the Illinoian age soils in Indiana and Ohio (see Table 27.) The negative values in adjacent soil regions appears to clearly indicate that farm operators in both the older soil regions and the younger soil regions are removing more nutrients from the soil in the process of crop production than are being replaced by fertilizers and by alfalfa or clover in the crop rotation system. The values on the Wisconsin age soils show the need to improve fertilizer programs and to examine the rotation system more closely, because the potential for improved yields is greater than on the older soils where less severe removal of nutrients is taking place. In Illinois, farm operators in both soil regions are removing more nutrients from the soil than are being replaced by proper fertilizer application rates and by alfalfa or clover in the crop rotation system. All soil regions in the study areas appear to need to increase fertilizer application rates to obtain optimum yield levels over a sustained period of time.

Table 27. Salter Productive Balance Values for Crop Rotation Systems in Study Areas, by Soil Regions

	Illinois	Indiana	Ohio
Illinoian Soil Region	-0.59	-0.54	-0.48
Wisconsin Soil Region	-0.68	-0.87	-1.05

The average number of livestock units per farm in the Wisconsin age soil regions is significantly greater than the average number of livestock units in the Illinoian age soil regions in Indiana and Ohio. The larger average number of units on the younger soils (see Table 25) seems to further support the designation of a corn-livestock farming type for these regions. The smaller average number of units on the older soils apparently shows the mixed farming type designation is appropriate for these regions. The average number of livestock units per farm is not significantly different between the soil regions in Illinois. However, the somewhat greater number of units on the older soils compared to the younger soils relates to the somewhat greater percentage of farmland used for pastures and pastured woodlots on the older soils (see Table 22.)

Farm Ownership and Labor

The analysis of the relationships between the soil regions and farm ownership and labor shows that there are no significant differences in the variables tested. The total number of farm laborers, the number of family laborers, the months of labor applied to the farm per year, the ownership of the farm, and the age of the farm operator do not seem to vary between the adjacent regions of the study areas (see Table 28.)

The average age of the farm operators in the Wisconsin age soil regions is not significantly different than the average age in the Illinoian age soil regions. The relatively similar average age of farm operators in all soil regions seems to negate the earlier contentions of Hart[10] and Sitterley[11] that there was a relationship between older farm operators and the older soils.

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10. Hart, *op. cit.*
11. Sitterley, *op. cit.*

Table 28. Farm Ownership and Farm Labor in the Study Areas, by Soil Region

	Illinois		Indiana		Ohio	
	Ill.	Wis.	Ill.	Wis.	Ill.	Wis.
Number of Laborers	2.4	2.1	2.0	2.4	2.2	2.3
Family Laborers	2.1	1.8	1.9	2.0	2.0	1.8
Months Labor/Year[1]	18.2	18.8	16.8	21.1	18.9	20.6
Full Ownership	28%	12%	60%	32%	40%	48%
Part Ownership	72%	64%	28%	36%	48%	32%
Tenants	0%	24%	12%	32%	12%	20%
Age of Operator	48.5	53.6	49.8	45.1	52.4	53.3

1. The months of labor per year are the total of all farm workers, so the total can easily exceed 12 months, as in this study.

Land Value Per Acre

The relationship between the adjacent soil regions of each study area and land value per acre is as follows: value of land per acre is significantly higher in the Wisconsin age soil regions than in the Illinoian age soil regions. The much higher average value per acre of land exclusive of buildings and other improvements in the younger soil regions compared to the older soil regions appears to indicate the generally greater natural fertility of the younger soil region and the direct variance of land value per acre and agricultural productivity as suggested by Ottoson[12] and Bushnell[13] (see Table 29.)

Table 29. Land Value Per Acre in Study Areas, by Soil Region

	Illinois	Indiana	Ohio
Illinoian Soil Region	$74.08	$148.20	$172.68
Wisconsin Soil Region	$327.92	$319.04	$270.76

12. Ottoson, op. cit.
13. Bushnell, op. cit.

CHAPTER V. A SUMMARY OF THE FACTORS ANALYZED IN THE THREE STUDY AREAS AND CONCLUSIONS

Summary

The preceeding analyses of the independent variables, anticipated as being integral parts of the agricultural systems of the contrasting adjacent soil regions, have shown that these variables are influenced to varying degrees by their association with the soil regions. Some variables exhibit significant association with the soil regions while other variables do not. The variables which show a significant difference between soil regions in all three study areas seem to be the most important variables within these particular agricultural systems. Six variables analyzed in this thesis are significant at the .01 level in all three study areas (see Tables 18 and 19.)

The significant difference in the Storie Index in each study area and the significant difference in value of land per acre in each study area seem to substantiate the earlier contentions that the "planosolic" soils are considerably lower in natural fertility and in value for general agricultural production.[1] The significant difference in the type of artificial drainage in each

1. See pages 46-47 of this thesis, Chapter II, "Resultant Soils--General."

study area appears to support the soil studies in all three states which cite the disadvantage of the claypan subsoil in the "planosolic" soils.

The significantly greater percentage of land devoted to cropland on the younger soils in each of the study areas and the significantly greater percentage of woodlots on the older soils in all three study areas seem to indicate a more intensive use of land on the younger soils and more land reverting to underuse or non-use on the older soils, as suggested by Hart and by Bushnell.[2] The significantly greater percentage of cropland planted to corn in each of the Wisconsin age soil regions than in each of the Illinoian age soil regions appears to support the earlier findings of Ross and Case, the corn belt maps of Rose, and the 1964 Census of Agriculture data.[3]

Five other variables are significant in two of the study areas and approach the .01 level of significance in the third study area, meaning that they probably can be considered as integral variables of the different agricultural systems in the adjacent soil regions (see Table 18.) The corn yield is significantly higher on the Wisconsin age soils than on the Illinoian age soils

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2. See page 63 of this thesis, Chapter III, "Land Use."

3. See pages 72-73 of this thesis, Chapter III, "Crops."

in the Illinois and Indiana study areas and approaches the .01 level of significance (.04 in the Ohio study area.) The yield differences between the adjacent soil regions tend to uphold the earlier statement that the fertility level for corn is higher on the younger soils and seem to support the findings that corn has greater importance on the younger soils.

The percentage of cropland planted to soybeans is significantly greater on the Illinoian age soils than on the Wisconsin age soils in the Indiana and Ohio study areas and approaches the .01 level of significance (.065 in the Illinois study area.) The differences in percentage of cropland devoted to soybeans seem to uphold the statement by Weaver that soybeans are the chief crop on the "planosolic" soils and tend to usurp acreage from other crops, especially wheat and hay.[4] The phosphorus, potassium, and total fertilizer application rates are significantly greater on the Illinoian age soils than on the Wisconsin age soils in the Illinois and Ohio study areas and application rates of phosphorus (.035 level of significance), potassium (.034 level of significance), and total fertilizers (.034 level of significance), approach the .01 level of significance in the Indiana study area. These greater fertilizer applica-

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4. See pages 75-76 of this thesis, Chapter III, "Crops."

tions on the older soils seem to point out the generally lower fertility level of the Illinoian age soils and seem to support the contention that soybeans are of greater importance on the older soils.

Six variables are significant in the Illinois study area, but not significant in the Ohio and Indiana study areas (see Table 18.) The relatively large number of variables significant in only one of the study areas apparently indicates two basic differences between the Illinois study area and the Ohio and Indiana study areas. First, the Illinois study area has grassland soils while the other two study areas have forest soils. Second, the emphasis of agricultural production is on slightly different end-products in Illinois than in Ohio and Indiana, making the farming type classifications different for the Wisconsin age soil region in Illinois than for those in Ohio and Indiana (see Table 24.)

The significantly greater percentage of cropland devoted to wheat and oats on the Illinoian age soils than on the Wisconsin age soils in the Illinois study area, combined with higher fertilizer application rates for nitrogen, phosphorus, and total fertilizers on the older soils than on the younger soils, seem to support the earlier classification of the Illinoian age soil region as a mixed farming region. Thus, a wider variety of crops tend to be emphasized under such a farming type than under a cash grain farming type stressing corn and soybeans, as in the Wisconsin age soil region in Illinois. These summary statements appear to be upheld by the significantly higher wheat yields on the Wisconsin age soils than on the Illinoian age soils, because the tendency is towards higher yields with fewer acres planted to a particular crop than with more extensive acreage. Capital and especially labor seem to become more intensified in an effort to produce a successful crop when less acreage is involved.

The significantly higher soybean yield on the younger soils than on the older soils in the Illinois study area suggests a similar high level of importance for soybeans in both regions of this study area and the higher level of natural productivity on the younger soils. Soybeans are an integral part of the cash grain farming type on the younger soils while soybeans are an integral part of the mixed farming type on the older soils as an income producing crop.[5]

One other variable, the Salter Productive Balance value, seems to suggest the basic differences between the Illinois study area and the Indiana and Ohio study areas. The Salter Balance is significantly different between soil regions in Ohio and Indiana, but not

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5. See page 75 of this thesis, Chapter III, "Crops."

significant in Illinois. Perhaps the cash grain farming type on the younger soils in Illinois removes less nutrients from the soil than the corn-livestock farming type on the Wisconsin age soils in Indiana and Ohio.

The agricultural activities in each of the six soil regions were analyzed by converting livestock and crop production to common units.[6] The varying intensities of production were differentiated by weighing the values so as to arrive at a proportion of agricultural activity value for each crop and for livestock in each soil region. The analysis used man-days per acre of crops or per head of livestock as a unit of measurement.

The results of the analysis appear to support the earlier classifications for the various soil regions (see Table 24.) The older soil region in each of the study areas has the growing of soybeans and corn as the two major agricultural activities, accounting for about three-fourths of the total activity. In each case, livestock is the number three agricultural activity. These regions seemingly are correctly classified as mixed farming type regions. They each emphasize soybeans and corn and produce relatively important amounts of wheat and oats and livestock.

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6. M.H. Yeates, An Introduction to Quantitative Analysis in Economic Geography, McGraw-Hill, New York, 1968, pp. 35-40.

Production of corn and livestock, especially hogs, accounts for about three-fourths of the agricultural activity in the younger soil regions of Ohio and Indiana. In each case soybean production is the number three agricultural activity. The heavy emphasis on corn production with its livestock counterpart classifies these two soil regions as corn-livestock farming type regions.

The younger soil region in Illinois appears to be different. Production of corn and soybeans account for nine-tenths of the agricultural activity. Very little livestock is found in the region. The Wisconsin age soil region of Illinois can be classified as a cash grain farming type region with emphasis on corn and soybeans.

Conclusions

The above analysis of the factors of agricultural production in the study areas in relation to the contrasting adjacent soil regions seems to indicate that this study has accomplished, at least in part, what it set out to prove. The differences in agricultural systems between the adjacent soil regions have proven to be somewhat subtle variations in the approach to farming by the farm operators, in the crops emphasized in the agricultural production process, and in the methods emphasized in producing these crops. It has taken the

examination of numerous variables in analysis of variance and Chi-square testing to sort out those variables in the agricultural systems which are significant in each of the study areas.

The number of variables found to be significant for each study area in this thesis does not appear to be the result of coincidental differences in other factors than the contrasting soils. Thus, it seems reasonable to accept the initial research hypothesis that contrasting adjacent soil regions influence differences in the agricultural systems of the regions in question. Furthermore, the secondary hypothesis that similar agricultural factors contrast in each of the study areas, indicating that a similar degree of contrast exists in each area, can be accepted in part. Examination of the variables appears to show a greater similarity of contrast, especially the degree of contrast in the Ohio and Indiana study areas. A different degree of contrast is evident in the Illinois study area as described below.

At the outset of this research study four contributions were expected to result from the analysis of the agricultural systems of the three study areas.[7] It is felt that each of these contributions has been

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7.. See page 33 of this thesis, Chapter I, "Methods and Anticipated Results."

presented successfully.

It was anticipated that this study would reiterate the value of using soil data to verify the existence of contrasting physical regions. The examination in pertinent literature of the five factors of soil formation seems to clearly point out the primary importance of the time factor in soil development for the regions under investigation in this study.[8] The collection of soil data for individual farms in the soil regions is not meaningful by itself, but incorporation of such data into the Storie Index makes it more understandable and completes a picture of soil productive capacity. The index, significantly different between soil regions in each study area, seems to be a reliable method of clearly distinguishing the natural fertility difference between soil regions. Thus, soil data can be of value in indicating the presence of contrasting physical regions.

The fertility difference between soil regions appears to be greatest in the Illinois study area. There is a significant difference in corn, soybean, and wheat yields between the two soil regions in Illinois while there is a significant difference only in corn yields between soil regions in Indiana and Ohio. The

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8. See pages 41-44 of this thesis, Chapter II, "Time."

significantly higher yields on the younger soils come despite significantly greater fertilizer application rates for soybeans and wheat on the older soils. There is a significant difference in fertilizer application rates only for soybeans in Ohio and Indiana. The fertility level seems to be higher in the Wisconsin age soil region of Illinois than in the other two Wisconsin age soil regions and lower in the Illinoian age soil region of Illinois than in the Illinoian age soil regions of Ohio and Indiana (see Table 26.)

It was anticipated that this study would provide a better insight into the role of soils in influencing differences in agricultural systems. The analysis of the data collected in this research study seems to indicate a definite direct relationship between soil differences and differences in agricultural systems. A factor of the agricultural systems which is significant in only one study area, such as soybean yield, could possibly be explained by influences other than soil differences. One factor is significant only in Ohio, one only in Indiana, and six only in Illinois. A factor significant in two areas, such as corn yield, probably can be attributed to soil influences, but possibly not. Two factors are significant in Chio and Indiana, one factor is significant in Illinois and Indiana, and three factors are significant in Illinois and Ohio. A factor significant in all three areas leaves little doubt but what it is influenced by differences in soils. Six variables are significant in all three areas. Five of the six variables significant in two areas approach the .01 level of significance in the third area. Thus, eleven out of the forty-four variables analyzed apparently are influenced significantly by variations in soils between the adjacent study regions (see Tables 18 and 19.)

The number of significant variables in this study seem to support Bushnell's contention that despite technological improvements, differences in soils are still reflected in differences in land use and therefore in varying agricultural systems.[9] The number of significant variables thus permits acceptance of the initial research hypothesis that soil regions influence variations in agricultural systems.

The influence of soils on differences in agricultural systems and more specifically on differences in farming types appears to be most strongly developed in the Illinois study area. In Illinois, seventeen variables are significant compared to twelve in Ohio, and eleven in Indiana. It can be stated that the Illinois study area appears to be distinctly different from the

9. See page 77 of this thesis, Chapter III, "Yields and Fertilizers."

Indiana and Ohio study areas. Six variables are significant only in Illinois. The Wisconsin age soil region in Illinois is classified as a cash-grain farming type as opposed to a corn-livestock farming type for the Wisconsin soil regions of Ohio and Indiana. The three Illinoian age soil regions apparently are similar because of the emphasis on soybeans and corn in a mixed farming type for each of these regions. Perhaps the greater influence of soils on the agricultural systems of Illinois is due to greater fertility differences between the soil regions there and perhaps it is due to the grassland soils--unlike the forest soils of Indiana and Ohio.

It was anticipated that this study would indicate the factors within the agricultural systems which one could expect to vary significantly with differences in soils. Actually, all of the factors examined in this study were expected to be significant because of previous studies reviewed in pertinent literature. However, given a similar physical environment to that of the study areas, with climate, topography, vegetation, and parent material kept constant, each of the variables which is significant in any one of the study areas could possibly vary with differences in soils. It seems likely that a variable significant in two areas has a better chance of being significant in another study.

A variable significant in all three areas has the best chance of being significant in another study.

It was anticipated that this study would indicate the need for further studies of a similar nature in other areas to demonstrate the role of soils in influencing land use patterns and agricultural systems. This study clearly demonstrates that contrasting adjacent soil regions influence the agricultural systems imposed on them. Furthermore, this study demonstrates that a similar degree of contrast can and does exist between the adjacent soil regions in Ohio and Indiana, while a greater degree of contrast seems to exist between the adjacent soil regions in Illinois.

Despite the significant findings of this study, four needs appear to be unsatisfied by the results of this research. First, there is a need to demonstrate that the variables significant in all three study areas are "key" variables which can be expected to be significant under similar conditions elsewhere. Second, there is a need to demonstrate which of the other variables, significant in one or two of the study areas can be or are significant elsewhere. Third, there is a need to determine if other variables, not significant in the study areas, would be significant under similar conditions elsewhere. Fourth, there is a need to determine if the apparent variation in degree of contrast between grassland soils and forest soils in terms of number of significant variables is found under similar conditions elsewhere.

This thesis is limited temporally and spatially. In other locations or at other times, where agricultural practices and/or physical factors may vary markedly from the study areas examined herein, the need may arise to employ other variables in analyzing the influence of soils on agricultural systems. However, the factors selected for analysis in this study, the methods of analysis, and the results, each may provide a starting point for other geographical studies of soils and agricultural systems.

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