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SOME RELATIONSHIPS BETWEEN LAND
USE AND SELECTED NATURAL LAND TYPES IN THE
LANSING REGION OF MICHIGAN

By

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PART I INTRODUCTORY

GENERAL INTRODUCTION

The Problem

This study of the relationships between selected natural land types and land use in the Lansing Region of Michigan is an attempt to measure the quantitative effects of differences in the natural environment (as measured by natural land types) on resulting land use.

It is a well-known ecological principle that plants and animals vary in their kinds and distribution in accordance with natural conditions of environment. It is in agreement with this principle that the hypothesis is made in this study that change in environment has some comparable effect on man's use of land.

If man is a rational creature that acts in some predictable manner to combine the physical realities of his natural environment with the economic realities of the price system, it should be possible to develop a system or theory to describe this action. It is a second hypothesis of this study that this can be done.

Studies of this kind are not new. Probably the German, Von Thunen (41), was the first to theorize as to how man would use land for agriculture within one given natural environment. Weber (43) expanded Von Thunen's ideas to all economic activity of man, but still remained within the theoretical framework of a given environment.

Aereboe (1) was the first to speculate on how differences in soil affected man's use of land within a given economic region. Brinkman (6), furthering these ideas, arrived at a scientific dilemma by

concluding that although a theory could be developed to explain how a given land use pattern could develop, it would be impossible to use the theory because of the impossibility of characterizing natural environments by some scientific classification system. He apparently gave up at this point.

With the development of the natural land type concept, the dilemma that had faced Brinkman seemed to disappear. Here was a scientific system of natural environment classification that seemed to satisfy the needs of explaining differences in land use within a given economic environment.

This study proposes to discover if differences in natural environment as measured by this natural land type concept are reflected in differences in man's use of land. If they are, it is the aim of this study to develop a theory that will explain how these differences in land use could have come about.

Purpose and Scope of Study

The original purpose of the study was to test to see if land use varied by natural land type and if it did, to explain how and why particular patterns of land use came about.

After almost two years' work gathering statistics with the above purpose in mind, it became evident that statistics simply were not available to show why a particular pattern of land use had developed on one particular natural land type. In order to salvage what work had been done, the purpose was changed. In addition to attempting to prove that land use differed between natural land types, it was decided

that perhaps some framework of studying land use could be developed that would provide a guide for statistical studies of land use so that many of the errors that had been made by the author in his quest to find out why certain land uses existed, could be avoided in the future. Economic theory was selected as the medium in which the outline for land use studies was to be written. The thesis as it finally evolved consisted of two parts: one, to show that land use differed between natural land types and secondly, a distinct section having little relationship to the first, showing by theoretical methods how a system of study could be designed to study land use in an area.

The scope, then, of the investigation includes two categories of study, statistical and theoretical. The statistical section consists of an inquiry into the relation of agricultural land use to selected land types in the Lansing Region of Michigan. Specifically, the statistical work includes the co-relationships existing between five natural land types in the Lansing Region and agricultural land use on each of these natural land types. The effect of farm size on land use is observed. Studies of field pattern and farm pattern by natural land types are made. A discussion of yearly changes in land use is included.

The theoretical section of the study includes a review of literature pertinent to land use theory. Economic models and concepts are developed deductively in an attempt to explain such land use phenomena as farm size distribution, land use intensity and land use distribution by natural land type in a given static theoretical situation.

Finally out of the theory section a program or outline for land use pattern studies is evolved which the author believes can be used as a pattern for studying the why and how of land use in local areas.

The scope of the investigation, while seemingly disjointed and uncoordinated, provides some insight into problems facing land use planners and other land utilization workers. No claims are made that this study is complete. The investigation is designed to provide a beginning method of study of land utilization in a local area, employing the natural land type idea.

METHODS OF STUDY

The Land Classification System

The land classification system used to characterize the differences in natural environment is known as the natural land type, and, as used in this thesis, was developed some years ago by Veatch (40).

The same concept has been used with some alterations by Milne (26), ~~STORIE~~ ~~Shaw~~ (29) and others.

Veatch's system of classification, like other genetic systems, rests on the principle that the characteristics used for classification lie inherently within the phenomena being classified. This particular system of land classification, the natural land type, employs such criteria as soil type, surface configuration, stream pattern and relief, as defining features.

The scale, or order, of classification has been arrived at deductively. This appears to be the major weakness of the system for utilization studies. Nevertheless, the system is relatively unchanging.

This thesis attempts to test the utility of such a system as an aid to land use studies.

Intuitively, it would seem that a natural land classification system would be more valuable in agricultural land use studies than in urban studies. This can be explained by the fact that the more closely related the particular use under consideration is to the natural land, the greater the effect will be of changes in the land on the use. In this study the land considered therefore is mainly agricultural land. It is felt that if the natural land type concept has validity for use studies, it should certainly indicate it on agricultural land.

Statistical Methodology

The usual procedure of studying land use in an area is to sample area blocks of from several hundred to several thousand acres each. All uses are determined in each block and presented in both table and map form. This is an excellent but costly procedure. For this study involving parts of ten counties and about ten thousand farms this process of field mapping was out of the question because of a lack of money to do the field work. A procedure of second best approximation had to be developed.

First, a method using mailed land use questionnaires was used. After several hundred returns were received, it became evident that this system would not succeed because of so many errors and omissions in filling out the questionnaires. Other sampling systems were tried and abandoned. The one finally selected consisted of using Production Marketing Administration data collected in each sample county, supported

by census information, data collected from farm-accounting farms from the Agricultural Economics Department of Michigan State College and data from a variety of other sources.

In addition to collecting samples randomly scattered over each land type, five areas of four sections each were selected to study farm and field pattern on each of the selected natural land types.

The aim of the methods used was not to obtain as precise a picture of land use as could be had but rather to get as precise and reliable a sample as possible with the resources available for doing the job.

The entire section on present land use leaves much to be desired from a research standpoint. It is realized that the data could be improved. At the same time a fairly accurate picture of land use is presented.

Theoretical Methodology

Deductive theory is used as an analogy to reality in an area where the factors involved are too complicated to be grasped and understood easily. Generally not a completely perfect analogy is obtained or no simplicity would be gained by using theory. Therefore only the more important factors of a situation are studied. A perfect theory of land use would be a regression equation in which all the factors affecting land use were included in their properly weighted relationships. This would be an impossible task since the techniques for isolating many of the factors have not as yet been developed.

The procedure used to develop theoretical models of land use is one in which, if given perfect knowledge about a static situation of

prices, production conditions and pattern of natural land types, the rational land use would be determined, with the explicit assumption that entrepreneurs attempt at all times to maximize profits. This is not a real world situation but is hoped to be sufficiently like the real world to be of value in explaining experimental data for use in the real world.

THE AREA UNDER STUDY

General Description of the Area

The Lansing region is an economic sub-region of Michigan. It comprises an area about 65 miles long from north to south and 55 miles wide from east to west at the widest part. The region roughly resembles the shape of a pear with the stem to the north. The area enclosed is about 2500 square miles and includes parts of ten counties. The extent of the region, after Thaden, is shown on Figure 1.

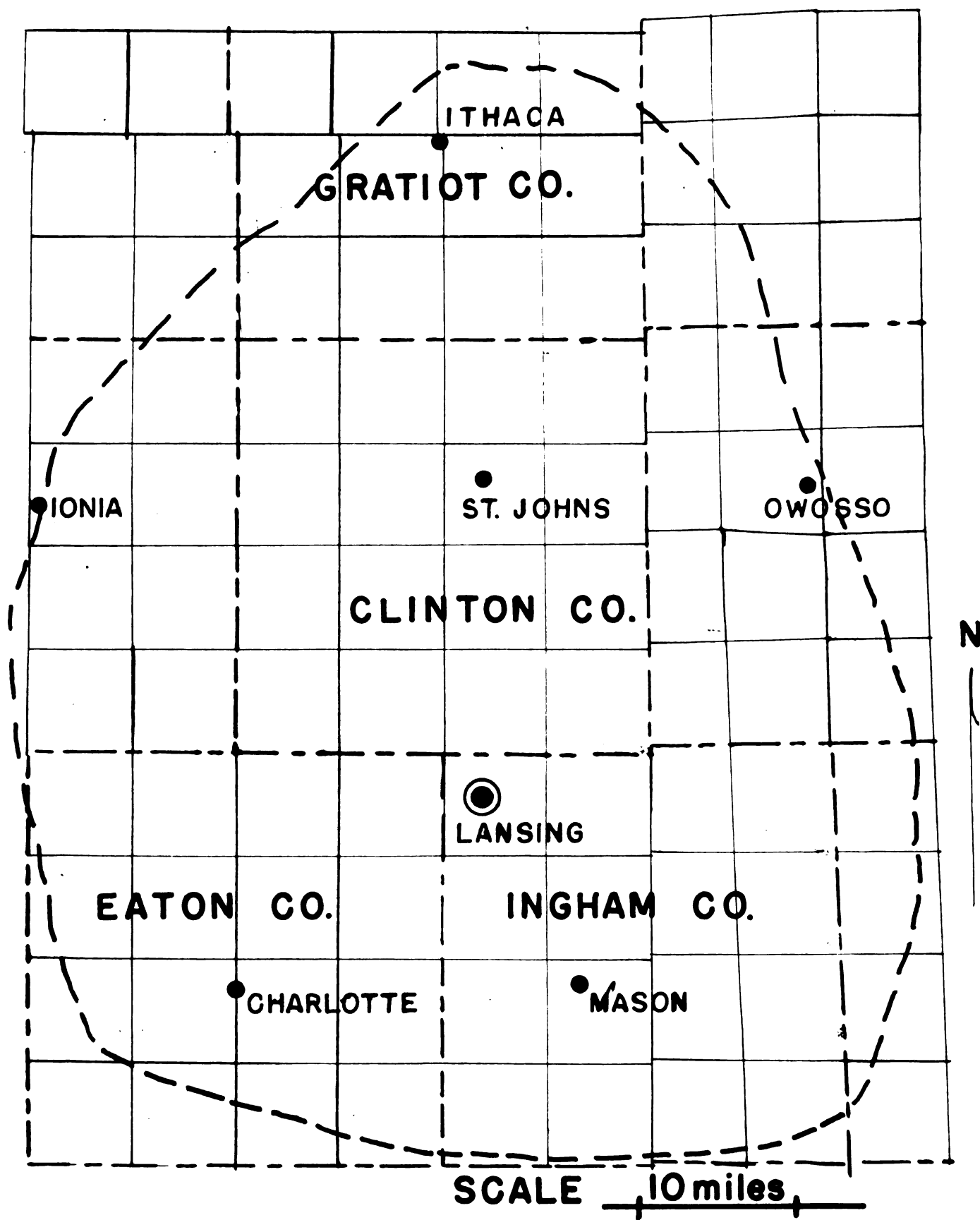
The basis for the region has been given by Thaden (34). He considered the region as the zone of influence of the largest city, Lansing, over its surrounding hinterland. The area of the region corresponds closely to the "milkshed" of Lansing or to the Christmas shopping area. The sub-region is an order of economic and social unit which lies between the smaller town-community and the larger regional community. For example, the Lansing sub-region is one unit of many comparable units in the Detroit zone of influence. In turn, the Lansing sub-region is comprised of many smaller economic and social units known as town-communities. The Mason community is one such unit.

Lansing, the central city and the large city of the region, lies in the northwest corner of Ingham county. The population for 1950 is given as 91,678 people. The population of the city with its surrounding fringe area is about 130,000 people.

The Lansing region consists of about fifty-five town-communities, each of these communities consists of the village and the farming hinterland. Within the farming area are numerous neighborhoods which comprise for the most part social rather than economic units.

FIGURE I.

THE LANSING REGION



Like its satellite communities, the Lansing region is also composed of economic and social units. In this case, town-communities are the building blocks. The structure of the region simulates that of the town-community, having at the center the structures associated with a city. Beyond the city itself, lies the urban-rural fringe area and beyond this, the farming community hinterland.

Almost the entire region lies in the dairy and general farming area of central Michigan. There is a small section in the northeast part which lies in the cash crop region of the lake bed plain.

The Lansing Region itself lies within a larger economic region that has the Detroit Metropolitan area as a hub. This influence of Detroit is particularly noticed in both industrial and agricultural production. Fluid milk is the most common agricultural commodity affected.

Physical Features

Surface Geology. The Lansing Region lies in the Eastern Lake Section of the Central Lowland Physiographic Province of the United States. The land surface is composed of glacial till, deposited as a level to undulating or moderately rolling glacial plain. Most of the area is composed of undulating till plains with some smooth to pitted outwash plains occurring locally. Moraines are a common feature of the landscape, as are eskers, small potholes and low shallow swells. Relatively broad glacial drainageways cross the area at intervals. The only truly level land of the entire region occurs on old lake bed plains in the northeastern part of Clinton County and farther to the north and northeast in Gratiot and Shiawassee counties. Locally, there are flat

muck plains as around Stockbridge and in Chandlers Marsh, northeast of Lansing.

The main drainageway of the area is the Grand River. Tributaries of this river drain almost the whole region, but imperfectly. The broad plainlike divides and the shallow drainageways twine in haphazard fashion. Dissection of the upland has not proceeded to any extent except along the banks of the Grand River and there for a very short distance inland. The undissected condition of the upland caused by the youthful stage of drainage has left hundreds of small to sizeable areas of muck and peat. This is particularly true in the south half of the region. The general direction of drainage is northwest. The maximum relief difference in the region is about four hundred feet with most of the land lying a little less than 900 feet above mean sea level. Average relief differences are not greater than fifty to seventy feet on most land types.

Natural Vegetation. Originally a dense growth of mostly deciduous trees covered the entire area. Local areas of oak openings occurred and in Eaton County there were a few scattered prairies. Swamp prairies of tall sedges occurred on the broad muck plains in the area. In general there existed a correlation between soil character and timber species. The muck plain occupying the wettest position supported marsh sedge and tall grasses. The drier parts produced red maple, willow, tamarack and aspen. Some marshes sustained a leather-leaf, sphagnum, cranberry-type bog.

The lowland mineral soils with poor drainage maintained large individual trees of elm, ash and red maple, with butternut, black walnut and cottonwood scattered throughout.

The upland soils supported three types of trees. In some of the very sandy sites, as around Pine Lake, pines occurred. On soils of intermediate texture there occurred an oak-hickory association with a predominance of oak; the heavier-textured uplands produced a maple-beech forest with considerable hickory, oak, black cherry, basswood and ash as associated species.

Soils. The soils of the Lansing Region belong to the gray-brown podsollic great soil group. They are formed mostly from calcareous glacial drift, said by Leverett (23) to have been deposited 15,000 to 20,000 years ago. The drift varies in depth from nothing at Grand Ledge where Pennsylvanian rocks outcrop to a depth of perhaps a hundred feet.

The soils differ widely in structure, texture, color, amount of organic matter, moisture and chemical composition. The most striking feature is the total lack of uniformity of soil in a small area. It is not unusual for one field to contain several soil types.

The upland soils vary from light-colored, loose, dry, incoherent sands of single grain structure, low water-holding capacity and low supply of available nutrients, to heavy, granular dark-colored clays, high in moisture-holding capacity and available nutrients. In association with these upland soils are organic soils, ranging from loose, granular mucks to woody and felt-like peats.

History of the Region

Early Settlement. The Lansing region was settled later than those regions to the south, east or west of it. This was due to the dominantly low wet swamps and dense forbidding forests.

The first land in the region was sold to land speculators a year or two before actual settlement began. In 1834 the first settlements were made in Ingham county at Stockbridge and Onondaga. It is probable that an earlier settlement was made in southwest Livingston county in 1833. By 1836 there were several settlements in the region, including Lansing. By 1840, many villages were competing for the trade of the area. In 1847, the Capitol was moved to Lansing, a city of less than half a dozen houses. The act of the legislature moving the Capitol to "the city in the forest" determined once and for all the center of trade and political life for central Michigan (12).

The pattern of early settlement developed from the southeast and the northwest. This was because the two existing roads at the time were the Ann Arbor to Kalamazoo road, to the south, and the Saginaw to Ionia road, to the north. The south road apparently was favored because of the opportunity to ship heavy goods down the Grand River from "Jacksonborough" to Lansing or Ionia. After 1843, when the railroad was finished through Jackson, the southern route was favored even more.

Early agriculture centered around farming the lands which could easily be cleared and planted. This in addition to the belief that the low wet lands caused the "ague" (malaria) led settlers to select the "oak openings", open park-like lands with scattered burr oaks, for the first farms in the region.

The usual pattern of farm settlement was to proceed to the place of settlement by ox team, erect a rude lean-to of logs and bark or sod and proceed to break land with a "stumpjumper" and a yoke of oxen. After the corn or barley was planted, the men, who quite frequently had

left their families behind in New York State or New England, built a rude log cabin and girdled trees for next year's crop before returning east for their families. The principal farm products grown were the grains, wheat, oats, barley, rye and corn. Hay was found growing wild. The animals grown were dairy cattle, beef cattle, sheep and horses.

Contrary to popular opinion, little of the timber of Central Michigan was cut for lumber by the earliest settlers. After the first wave of settlers had farmed the oak openings for a few years, they gradually moved back on the uplands where land with such soil types as Miami and Hillsdale was opened up. These soils supported heavy growths of oak and hickory. It is stated by Fuller (12) that traveling timber cutters cut and piled this timber on a custom work basis. The first year, this timber was allowed to lie in the fields and the farmer worked around it and the stumps. The second spring, the timber was burned.

While it is true that many of the early roads were plank or corduroy roads, this use accounted for very little of the original timber resources of south central Michigan.

Agricultural Development. By 1880, seventy-five per cent of the land in farms was cultivated, virtually the same per cent as was tilled in 1945. In 1880, approximately ninety-six per cent of the land was in farms (35), a higher percentage than in 1945. The major changes in agriculture since 1880 have been clearing more of the woods and developing more rotation pasture on already cleared land. Many of the farms of 1880 have since been abandoned to either idle land because of low productivity or converted to urban land.

Census figures show that there have been few changes since 1900 in the crops grown. Alfalfa has been introduced and many improvements have been made in varieties grown. Generally however, the crop and livestock load per farm has changed little. Size of farm has increased constantly. The number of horses has declined greatly to be replaced by machinery. Investment per farm in equipment has increased with a corresponding decrease in the amount of family labor.

Population Trends. The Lansing region is comprised of about 300,000 people living in parts of ten counties (37). The population growth has been rapid as can be seen in Table I. This table compares the growth of five counties making up the greater part of the Lansing Region, with the city of Lansing.

Table II gives the distribution of the population between four population classes in 1940 (37). It can be seen that at that time, urban population constituted about half of the total population of the region. About 70 per cent of the urban population was concentrated in the city of Lansing. It should also be noted that the farm population in each of the five counties listed was about equal. The rural farm population constituted about one-quarter of the total population. Village population, like rural population, was nearly the same in each of the five counties studied.

One class of population that has some bearing on this study is the class termed rural non-village, non-farm. This group is important since the numbers of this group vary directly with distance from Lansing. From the broad picture of land use this means that as distance from town increases, this group of population diminishes in numbers, hence in the amount of land use for rural residence and part time farm use.

TABLE I

POPULATION GROWTH FOR LANSING AND THE LANSING REGION FROM 1840-1950*

Year	Lansing Region Population	Lansing City Population
1840	10,517	-----
1850	33,619	1,229
1860	76,858	3,074
1870	121,823	5,241
1880	153,932	15,438
1890	160,022	13,102
1900	164,817	16,485
1910	173,734	31,229
1920	203,052	57,327
1930	207,582	78,397
1940	268,328	78,753
1950	327,217	91,678

* U. S. Department of Commerce, Bureau of the Census (37).

TABLE II

POPULATION DISTRIBUTION BY POPULATION CLASS
IN THE LANSING REGION IN 1940

County	Total	Urban	Population Class		Rural Farm
			Village	RNFNV*	
Clinton	26,671	4,422	4,399	3,094	14,803
Eaton	34,124	12,503	4,016	2,744	14,904
Ionia	35,710	10,481	6,636	5,069	13,702
Ingham	130,616	87,459	4,696	23,792	14,688
Shiawassee	41,207	17,551	5,801	3,016	15,140
Total	268,328	132,416	25,538	37,715	73,237
Per cent of total	100.0	49.3	9.4	13.8	27.1
* Rural non-farm, non-village population					

This can best be shown as in Table III which shows the percentage distribution of this class of population with distance from Lansing. Five townships starting with Lansing township, situated west of Lansing were selected to study the distribution of the rural non-village, non-farm population in 1940. The figures in per cent varied from 96 for Lansing township, which surrounds the city of Lansing to 5 per cent for Sunfield township, situated 24 miles west of Lansing.

Descriptions of Selected Natural Land Types

The natural land types selected from the Lansing Region for this study are shown on Figure 2. This map was taken from a larger natural land type map of the lower peninsula of Michigan ^{by} ~~by~~ Veatch (39). The Lansing Region comprises all the area on the map lying inside the heavy-dashed line.

Twenty natural land types occur within the boundaries of the region. Only five were sampled in this inquiry. These five are numbered after Veatch with the numbers 27, 1, 31, 15 and 11. The author selected geographic names to correspond to the numbers used by Veatch as follows: No. 27, Roxand; no. 1, Riley; 31, DuPlain; 15, Stockbridge and 11, Leslie. It was felt that geographic names might be easier to follow than the number system.

In the following section, the five natural land types selected for this study will be described with charts, verbal descriptions, photographs and maps.

Surface Configuration Profiles. One of the distinguishing features of a natural land type is the surface configuration associated with it.

TABLE III

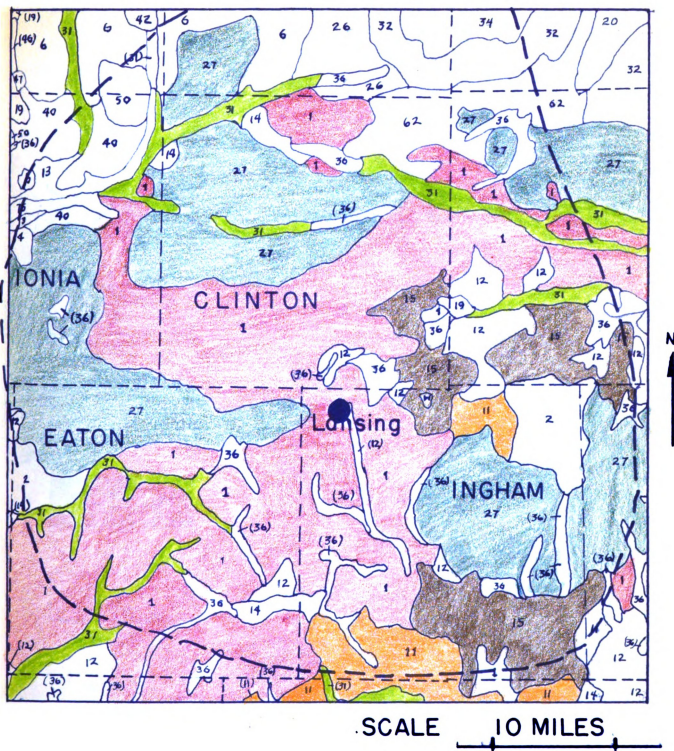
PERCENTAGE DISTRIBUTION OF RURAL NON-FARM, NON-VILLAGE POPULATION
WITH DISTANCE FROM LANSING*

Township	Rural non-farm, non-village population	Distance from Lansing
Lansing	96	0 miles
Delta	57	6 "
Oneida	19	12 "
Roxand	11	18 "
Sunfield	5	24 "
* U. S. Department of Commerce, Bureau of the Census 16th Census, 1940; population (37).		

FIGURE 2

NATURAL LAND TYPE MAP

20



See next page for legend

NATURAL LAND TYPE LEGEND

27

ROXAND NATURAL LAND TYPE

1

RILEY NATURAL LAND TYPE

31

DUPLAIN NATURAL LAND TYPE

15

STOCKBRIDGE NATURAL LAND TYPE

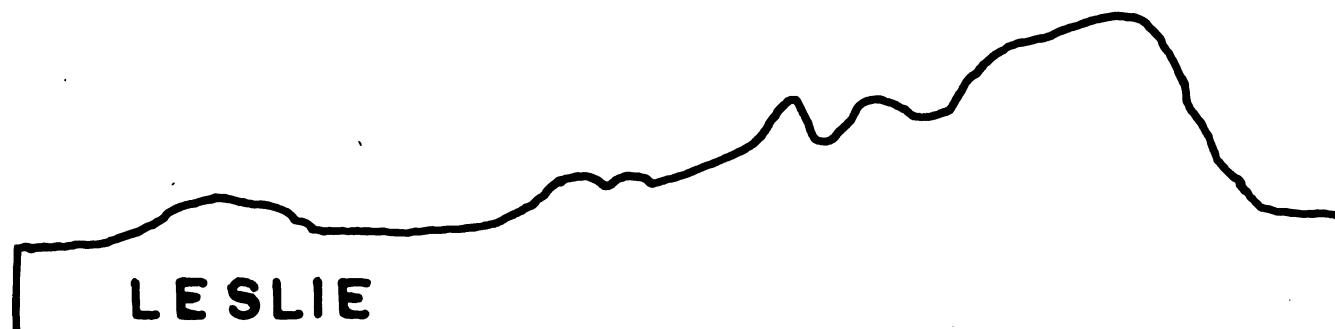
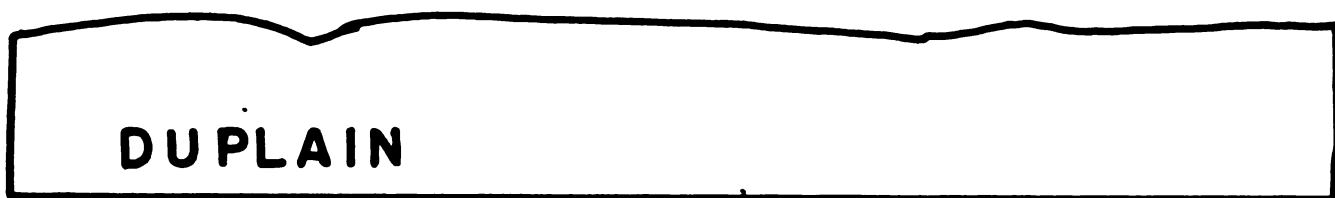
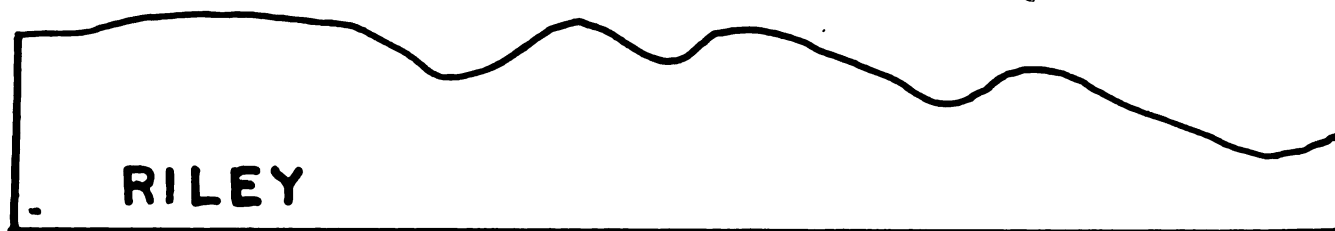
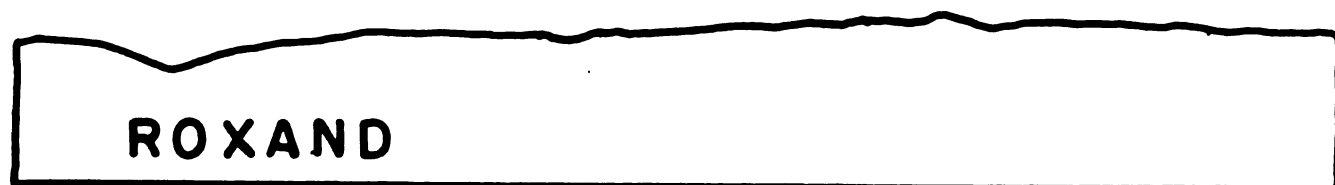
11

LESLIE NATURAL LAND TYPE

Figure 3 shows the relative differences between the five natural land types used in this study. It can be seen from the chart that there is considerable difference in the surfaces of the five types. The distance represented on the chart is two miles of surface. There is a vertical exaggeration of 22 times to accentuate the vertical differences in the relief. It should be observed that the Roxand type (No. 27) which is almost flat land has variations in the surface described as swells. The Riley type (No. 1) is smoothly rolling but can hardly be classified as rough. The DuPlain type (No. 31) has dips in the surface where streams and rivers flow. This type of land has an orientation not associated with the other land types. The surface profile shown here is a valley cross-section. If the profile had run parallel with the valley it would have been more nearly flat land. The Stockbridge type (No. 15) represents a complex surface of low hills and valleys with short slopes and low to steep gradients. The relief differences are no greater than for the Riley type but changes in topography in shorter distances give the area a more rugged appearance. The Leslie type (No. 11) has smoothly undulating to rolling topography with relatively broad areas between the swells or hills. The slopes are longer than on the other types represented here.

Roxand Type (No. 27 on the map). Plains of wet or semi-wet, dark-colored soils and low swells of lighter-colored soils make up this group. The flat, darker-colored phase may predominate with the higher drier land forming island-like swells; or the two conformations may be nearly equal in proportion, occurring in a succession of low rounded swells of upland with dark-colored valley flats and shallow-dished depressions.

FIGURE 3.
COMPARATIVE SURFACE CONFIGURATION
PROFILES OF FIVE NATURAL LAND TYPES



There are shallow drainage swales and pond-holes but few deep pot-hole depressions or sharp drainage hollows; the few streams present have not dissected the land. There are few lakes, some areas having none, and only a comparatively small number of muck or peat swamps. Elevation on the flatter land varies only from 8 to 10 feet and the difference between the flats and the crests of the higher swells is usually not more than 30 or 40 feet; slopes are simple and low in gradient.

Silt loam and clay loam coverings of 8 to 10 inches overlap a relatively impervious clay layer which is calcareous at depths of 18 to 36 inches. This layer rests on massive, fine-textured till clay which extends to depths of several feet. Stoniness is not a distinguishing characteristic, although locally, boulders may be scattered over the surface and in the till.

The darker soils are principally Conover and Brookston; the lighter-colored, Miami. There are also included patches and small bodies of miscellaneous soil types, classified as Napanee, Crosby, St. Clair, Allendale, Granby, Brady, Gilford and Carlisle and Kerston-type mucks.

The soils as a whole are medium to relatively high in natural fertility, are productive and durable under cultivation, and the land is suitable for dairying and a livestock type of farming.

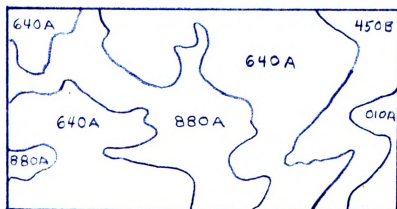
Figure 4 shows a photograph of the Roxand land type. The relatively flat surface should be noted. Some characteristics of use may be observed in the picture. The scattered woodlots and fine buildings are commonly seen on this land type.

Figure 5 gives the soil type distributions on a typical 80-acre farm of the Roxand type. Conover and Brookston soil types constitute

FIGURE 4
PHOTOGRAPH OF THE ROXAND NATURAL LAND TYPE



FIGURE 5
SOIL TYPE AND SLOPE CLASS MAP OF A TYPICAL 80 ACRE FARM
FOR THE ROXAND NATURAL LAND TYPE
(COURTESY SOIL CONSERVATION SERVICE)



010	ORGANIC SOIL	A	SLOPE LEGEND
450	MIAMI LOAM	B	0 - 2 %
640	CONOVER SILT LOAM	C	2 - 6 %
880	BROOKSTON LOAM	D	6 - 12 %
		E	12 - 18 %
			18 - 25 %

the major portion of the farm. The simple pattern of soils of this land type can be compared to the complex soil pattern of the Stockbridge type.

Riley Type (No. 1 on the map). This division comprises much of the land of the Lansing Region. It is characterized by local areas of rolling topography, a high proportion of land area in gentle to moderate slopes, a high proportion of wet lowland including peat and muck and a wide range and complexity in soil and topographic components.

The configuration features are mostly rounded, constructional in origin but having no orientation or pattern of arrangement. The depressional features are diverse in kind and arrangement. Glacial bowls, pockets, dips, broad shallow depressions; open, haphazardly arranged drainage swales, filled lake basins; numerous intermittent ponds and swales and occasional lakes occur. Upland features include glacial hillocks, ridges, rolls, swells, heads, spurs, and other conformations all rounded in character and composed of smooth short slopes. Much of the area includes broad swells of upland and sags of lowland, each component including a variety of configuration forms within its own micro-relief.

This land appears on either till plains or recessional moraines. Local relief is generally less than 50 feet but may be as great as 100 feet.

The principal soil types are the Miami series, including both the relatively more permeable loam and the heavy clay loam underlaid by tight, impervious clay till.

The land when viewed from the air gives an impression that the darker-colored pattern of the lowlands was laid over the relatively

lighter-colored base. Various gradations of yellows, browns, blacks and grays appear in the pattern. The browns constitute hilltops, the yellow is found on the relatively eroded upland and the group blends into blacks in the lowlands.

Locally, there are inclusions of more friable and pervious soils such as the Hillsdale. Eskers and sand ridges cross the area as scattered bodies of Bellefontaine or Coloma types. The most common soil association is Miami, Conover, Brookston and muck, which in this case appears also as the drainage catena.

The original forest cover on the upland contained much sugar maple and beech. It is doubted, however, if these species were universally present and, if so, in greater number than white, red and black oak, elms, white ash, hickories and basswood. The lowland forest consisted of swamp white oak, elm, black ash, red maple, walnut and butternut.

Figures 6 and 7 show photographs of the area and a soil type map of a typical 80-acre farm. Attention should be drawn to the undulating nature of the topography and the more diverse pattern of soil types than was true for the Roxand type.

DuPlain Type (No. 31 on the map). The division includes land in narrow valley plains which for the most part are old glacial drainage ways. They are generally not more than two or three miles in width and are traversed by rivers. The rivers in places have cut a lower plain, a few feet deeper, which is floored with recent flood plain alluvium. One or two terrace plains above the alluvial bottom land may be recognized in some of the valleys. The old glacial alluvium is generally coarse in texture; it is gravelly, at least at the base of the deposition,

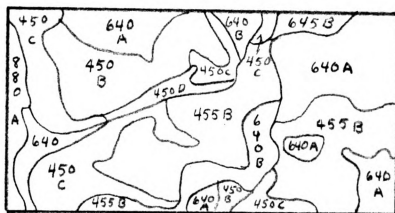
FIGURE 6

PHOTOGRAPH OF THE RILEY NATURAL LAND TYPE



FIGURE 7

SOIL TYPE AND SLOPE CLASS MAP OF A TYPICAL 80 ACRE FARM
FOR THE RILEY NATURAL LAND TYPE
(COURTESY SOIL CONSERVATION SERVICE)



450	MIAMI LOAM	A	SLOPE LEGEND 0-2 %
455	MIAMI-CONOVER COMPLEX	B	2-6 %
640	CONOVER SILT LOAM	C	6-12 %
645	CONOVER LOAM	D	12-18 %
880	BROOKSTON LOAM	E	18-25 %
		F	OVER 25 %

and even cobbly and bouldery locally. The plains are nearly flat but are intersected in places by inflowing streams from the adjacent high-land and contain very shallow dry depressions. The wet components are extensive flats having a high water table, large bodies of muck and linear bodies of swampy land bordering the channels of the rivers. There are a few lakes, but lakes are not a characteristic feature of the type as a whole.

The soils are various admixtures of the Fox, Oshtemo, Plainfield and Berrien types on the drier sites; and Brady, Gilford, Bronson, Granby and Maumee on the wetter. Dark-colored clay soils are a minor component; these are generally underlaid by waterlogged sand or sand and gravel at depths of one to three feet. There are occasional spots of dry prairie soil and marsh, undifferentiated loamy sand and gravelly soil consisting of alluvial wash at the mouths of drainage hollows from the adjacent high land, and yellowish and reddish-brown ochreous spots--a fraction of an acre or an acre or two in size--which may contain fragments of bog iron ore.

The wetter land supported a dense stand and tall growth of elm, silver maple, swamp white oak, white oak, ash, shagbark hickory and species such as cottonwood, willow and sycamore. The drier land supported an oak-hickory type of forest, with white pine common on the more northern areas.

The more loamy soils on the higher sites, and locally, the wet soils where provided with adequate drainage, are producing good yields of the staple farm crops and truck crops. Much of the land however, remains in woods, or is utilized only for pasture. It has only a low cropping

value because of flooding, impracticability of artificial drainage, intimate mixture of wet and dry land, low fertility and durability of soil, and in places, extreme stoniness.

Figures 8 and 9 show photographs of the land type and a typical soil type map.

Stockbridge Type (No. 15 on the map). This land type includes low-relief plains and mainly sandy soils. It comprises a complex of flat and pitted upland, swampy lowlands and soil variants of both.

The topography includes flat, rolling upland, with islands of low, narrow ridges lying from ten to thirty or forty feet above the swamp levels. The soils are dominantly Fox and Plainfield types with smaller amounts of Hillsdale, Miami, Bellefontaine and Coloma profiles, or variants of these. Various types of peat and muck and miscellaneous sandy, gravelly or clayey soils occurred on the lowlands. The organic soils have been classified as Rifle peat, Carlisle muck, Houghton muck, Foston muck and Greenwood peat. The mineral soil types which include Conover, Brady, Gilford, Granby, Brookston and Berrien types.

Lakes are relatively common in the lowland areas. Some have muck shores and bottoms while others are sandy. Some of the lakes are little more than sedge-filled marshes whereas others have high-banked shores and sandy beaches.

The variability of the soils and of the lakes produce rather poor agriculture and recreational land. Locally, drained areas of muck have an extremely high value for agriculture. Likewise, some of the lakes are in great demand for the recreational facilities they offer. In general this mixed condition of the land favors a conflicting mixed use.

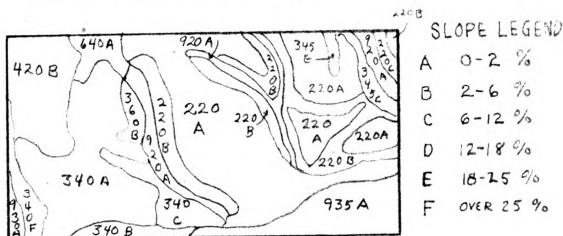
FIGURE 8

PHOTOGRAPH OF THE DUPLAIN NATURAL LAND TYPE



FIGURE 9

SOIL TYPE AND SLOPE CLASS MAP OF A TYPICAL 80 ACRE FARM
FOR THE DUPLAIN NATURAL LAND TYPE
(COURTESY SOIL CONSERVATION SERVICE)



220	OSHTENO LOAMY SAND	420	FOX LOAM
340	FOX SANDY LOAM	640	CONOVER SILT LOAM
345	FOX COBBLE LOAM	930	GRIFFIN, ALL TEXTURES
360	HILLSDALE SANDY LOAM	935	GENESEE, ALL TEXTURES
		920	WATKINS, ALL

Figures 10 and 11 show photographs of this land type and a typical soil type map of the land type.

Leslie Type (No. 11 on the map). This grouping comprises rolling and moderately hilly upland on which the Hillsdale type of soil predominates.

The land surface has the constructional rounded configuration features common to moraines and till plains--broad swells of upland indented by shallow basins and drainage swales, domes, ridges and valley depressions. In most of the areas, the difference in local relief is hardly more than 40 or 50 feet, slopes are smooth and have gradients less than 10 per cent, although locally some of the land is hilly and broken in aspect. Swampy valleys and basins are widely distributed and comprise 10 to 20 per cent of the total acreage in the larger separate areas. Lakes are present but not numerous enough to be an especially distinguishing characteristic; streams are relatively few.

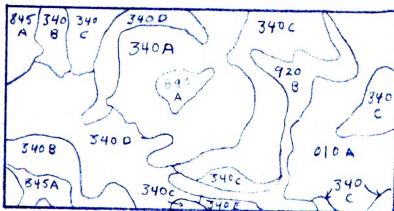
The dominant soil, the Hillsdale type, is distinguished by the peculiar yellowish color and friable, granular nature of the subsurface, clayey horizon of the soil profile. The profile is medium or even strongly acid in reaction to depths of 3 or 4 feet; the underlying glacial drift usually exhibits a strong influence from local sandstone and shale bedrock, but is not entirely devoid of limestone influence and, locally, both sands and clays may be moderately calcareous.

The soils are medium to low in organic matter, they are sandy loams and light loams in surface texture, with only medium natural fertility and productivity. They are adapted to a diversity of crops and, properly managed, are capable of remaining as permanently productive agricultural

PHOTOGRAPH OF THE STOCKBRIDGE NATURAL LAND TYPE



SOIL TYPE AND SLOPE CLASS MAP OF A TYPICAL 80 ACRE FARM
FOR THE STOCKBRIDGE NATURAL LAND TYPE
(COURTESY SOIL CONSERVATION SERVICE)



		SLOPE LEGEND	
<u>C10</u>	ORGANIC SOIL	A	0 - 2 %
<u>340</u>	FOX AND BELLE FONTAINE SANDY LOAM	B	2 - 6 %
690	BRADY SANDY LOAM	C	6 - 12 %
845	GRANBY SANDY LOAM	D	12 - 18 %
920	WASHTENAW ALL TEXTURES	E	18 - 25 %



land. The land is locally bouldery and in a few places, bedrock of sandstone lies at a depth of a few feet.

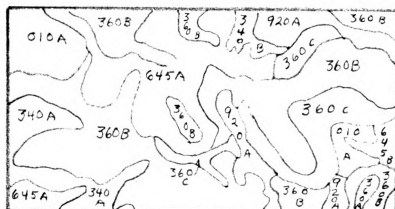
The Miami, Bellefontaine and Coloma soil types are closely associated with the Hillsdale. Moist loamy soils, the material of which has been largely washed in from adjacent slopes, occur in hollows and drainage swales, but the proportion of wet soils, either sandy or clayey, other than peats and mucks does not constitute over a fifth of the land.

Figures 12 and 13 show photographs of this land type and a typical soil type map of the land type.

PHOTOGRAPH OF THE LESLIE NATURAL LAND TYPE



SOIL TYPE AND SLOPE CLASS MAP FOR A TYPICAL 80 ACRE FARM
FOR THE LESLIE NATURAL LAND TYPE
(COURTESY SOIL CONSERVATION SERVICE)



010	ORGANIC SOIL	A	0-2%
340	BELLEFONTAINE SANDY LOAM	B	2-6%
320	HILLSDALE FINE SANDY LOAM	C	6-12%
245	CONOVER LOAM	D	12-18%
320	WASHTENAW ALL TEX. CL.	E	18-25%

PART II STATISTICAL SECTION

PRESENT AGRICULTURAL LAND USE

Selection of Sample Farms

Twenty natural land types occur within the Lansing Region. Because of the lack of precise land type and land use information, adequate samples for study could be obtained for only five natural land type areas. This number was thought to be sufficient to test whether or not land use varied by land type.

The land use sample farms were selected carefully from the records of the Production Marketing Administration in Eaton, Clinton and Ingham counties. Sample farms were selected for completeness of land use information for 1948, for conformity to the natural land type in which the farm occurred and for distance from the nearest town. In addition, only full-time farms were selected for the sample.

This study is based on the "Land Types of the Southern Peninsula of Michigan" by Veatch (39), in which the scale of the map necessitates the inclusion within an individual area on the map of many smaller areas which do not conform to that land type in soil, topography and other characteristics. (If the map were of a larger scale, these smaller areas would be shown as separate land types.) If a 100 per cent sample could have been used in this study, the bias produced by inclusions of non-conforming land in Veatch's scale of mapping would have been eliminated by the size of the sample. Since, however, a somewhat less than 10 per cent sample of farms in any land type area was used, detailed soil maps were utilized to check the conformity of each farm within a land type,

to that land type. If a farm did not conform in its characteristics to the natural land type it was supposed to represent, it was discarded from the sample. Detailed soil maps were available for only four counties in the region: Ingham, Eaton, Clinton and Livingston. However, only farms from Ingham, Eaton and Clinton counties were employed in land use sample. Livingston was not used since it would not contribute any additional land types, but only to the size of samples on land types already selected from the other three counties.

Bias of Production Marketing Administration Data

Data for land use information and size of farm were secured from the Ingham, Clinton and Eaton County offices of the Production Marketing Administration (28). Such data may and probably do contain a bias in land use. If the P. M. A. has any success with its allotment program, the land use must be different from that on non-co-operating farms. How much PMA data is biased is not known; it would require a comprehensive study to discover the extent of error. For the purpose used in this study, natural land type differences should reflect in use on PMA farms as well as on non-co-operating farms, so that it is felt that the utility of PMA data is just as great as an unbiased estimate of population differences on the various land types obtained through an unbiased sample.

Methods of Analysis of Production Marketing Data

In the following pages many statistical facts are to be found about land use. In a good number of cases the statement will be made that no information can be discovered in the data about the causes for certain differences. This is not to be taken as an evasion. It was felt that to

integrate theory with statistics in the same section would be a bigger task for the reader to interpret than the effort required would be worth.

The hypothetical explanation for some of the reasons behind land use are included in a separate section. Later on, a section integrating the statistical with the theoretical is included. Thus an attempt will eventually be made to state explicitly some hypothesis for causes in differences in land use by natural land type.

Total Land Use in the Agricultural Area

In any purely agricultural area, there are always certain other uses complementary to, or symbiotic to, the agricultural use. One major land use is always found associated with agricultural land use in even the most primitive society. This is transportation land use. Roads of some kind are always present as a complementary use to agriculture. In most countries advanced in technology, communication land use such as electric and telephone line right-of-ways occurs in association with farm land. In almost every agricultural area of the humid region, forest land occurs as a symbiotic use.

A non-symbiotic use to agriculture which occurs in many farming areas is idle land. This is land that may or may not have been used for agriculture in the past but at present maintains neither forestry or agriculture. Such land may be considered from the agricultural production viewpoint as creating space. In an agricultural community where spaces of idle land intervene between farms, increased production and marketing costs arise from distance of transport alone, without compensating increases in value of products sold. This accounts for the non-symbiotic

nature of idle land. Water resource land may fall into this non-symbiotic category. Recreation land may be either symbiotic or non-symbiotic depending on the nature of the recreation offered and the space occupied. If recreational land offers an increased market for farm products locally, the use of space may be offset by the increased value of the farm products.

In presenting a comprehensive characterization of land use in an area occupied mostly by agriculture, there are three pictures to view: the agricultural land use, the major uses symbiotic to agriculture and the non-symbiotic uses.

In the five natural land type studies^d, all but one, the Stockbridge type (No. 15), were occupied almost entirely by agricultural uses. Approximately .25 per cent of the land on all types was occupied by roads. This was due to the gridiron pattern of roads, with roads distributed in north-south and east-west directions at one mile intervals, on all land types.

The Stockbridge type (No. 15) had only 60 per cent of the land in farms. The remainder was in idle land or in State Game areas. The Rose Lake Wildlife Area and the Dansville State Game Area occupied large tracts of the Stockbridge land type. The peculiar mixture of soils, mainly wet lowlands and dry infertile uplands, plus the small farm sizes settled in the area, caused uneconomic farms to be developed that had to be later abandoned.

Table IV provides a picture of total land use on selected agricultural areas of each of the five natural land types studied. State Game Areas did not appear to differ essentially from other idle land in the region; thus, they were included as idle land on the table.

TABLE IV

USE OF LAND IN PER CENT ON A 2560 ACRE SAMPLE FROM EACH OF FIVE
SELECTED NATURAL LAND TYPES (ESTIMATED BY AUTHOR)

	Roxand (27)	Riley (1)	DuPlain (31)	Stockbridge (15)	Leslie (11)
Land in roads	.25	.25	.25	.25	.25
Land in farms	99.75	99.75	99.75	59.75	99.75
Idle land	.00	.00	.00	40.00	.00

Farm Land Use

After the broader picture of total land use in the agricultural hinterland is observed, the next aspect to be considered is the broad use of the farmland on the various selected natural land types. Table V gives a view of farm land use in two categories; tillable and non-tillable land.

Tillable land as used here includes all land plowed including plowed pasture and idle land. It specifically does not include all land that could be plowed. Non-tillable land comprises land used for roads, fences, ditches, homesteads, barnyards, paddocks, permanent pasture, woodlots, swamps, lakes, gravel pits and dumps. Land types 27, 1 and 31, the Roxand, Riley and DuPlain land types, all had about 75 per cent tillable land. Stockbridge type (No. 15) had 58 per cent and the Leslie type (No. 11) had 68 per cent tillable land.

Surface configuration and quality of soil appear to be factors that cause land to stay out of cultivation on all natural land types considered. Surface configuration includes two factors which cause land to stay out of cultivation: slope and drainage. If the slope is too great, modern machinery cannot be used and thus the land remains untilled. Undrained land such as that occurring in wet swales cannot be cultivated.

Quality of soil is an economic factor that may prevent cultivation. If the land is so unproductive as to be unprofitable, it will stay unworked. Other factors that cause land to remain untilled are 1) type of farming: livestock farming demands more land for fences, small paddocks and lanes than crop farming; 2) habits of the operator: Swiss farmers may use land differently than English American farmers (21), and 3)

TABLE V

USE OF FARM LAND BY NATURAL LAND TYPE

	Roxand	Riley	DuPlain	Stockbridge	Leslie
Per cent farm land tillable	78.38	75.71	75.04	57.78	68.06
Crop land	78.31	75.64	75.04	57.67	67.38
Orchard	.07	.07	--	.11	.68
Per cent non- tillable land	21.63	24.28	24.96	42.22	31.94

size of farm: small farms have a greater per cent of tillable land than large farms.

The per cent of tillable land is a relatively stable factor. Although the data ~~is~~^{are} not presented here, the census of 1880 compared with that of 1945 indicates that very little change has taken place on the various land types since that time in percentage of tillable land (35). This strongly suggests that the per cent of land tillable on any particular land type is more a function of natural land than it is of economic conditions or whims of farmers.

If each land type is analyzed individually, some of the reasons behind the percentages of tillable land existing on any natural land type may be hypothesized.

If the Roxand type (No. 27) is examined, the reasons for 25 per cent of the land remaining uncultivated may be found. Approximately 10 per cent of this land type remains in woods, but since most of these woods are found on the wet land that comprises about half the area, it is not the woods that prevent cultivation but poor drainage. Probably the main factors preventing cultivation in addition to wet land are institutional factors. Such uses as determined by the type of farming and the habits of the farmer are in this group.

It is probable that the longer this land type remains in farming, the larger the percentage of tillable land will be up to the point where virtually all the land is tilled. There are some areas that are difficult to drain. Few areas however are impossible to drain. As the land becomes drained, the woodlots will disappear in favor of the cultivated crops. As an example, in north Eaton county, it is not unusual to find

many individual farms on which 78 out of 80 acres of each farm is under cultivation. This happens to be in a well drained section. A few miles from here are farms that are not properly drained as yet that have only 40 to 50 acres out of 80 drained.

From observation and the history of drainage of this land type, it seems likely that the census of 1880 listed too much land as being tillable. If Roxand township in Eaton county is taken for an example, the land in farms has not increased since 1880. Neither has the per cent of land tillable increased according to the census of 1945. Even to the casual observer, the land that is tilled can be seen to be increasing due to increased drainage produced by ditching within the area. The only conclusion that can be drawn is that the estimates of tillable land were too high in 1880.

The Riley land type (No. 1) is comprized of undulating to moderately rolling topography. The slopes are short and frequently steep. In local areas slope too steep to easily till with modern equipment may comprise up to one-quarter of the land area. This is enough to explain the 25 per cent of non-tillable within the land type for these areas. In addition to the slope factor, the presence of swamps, swales, pond holes, and wet muck pockets accounts for some of the untillable land. It is unlikely that many of these wet areas will ever be drained due to the technical difficulties of drainage. At the present state of land use, woodlots frequently occur on upland soil that could be tilled if cleared. It appears likely that these woodlots will be cleared and the percentage of tillable land increased a few per cent.

Land type 31, the DuPlain type has 25 per cent of its land out of cultivation for several reasons. Much of the land within this type lies along the banks of streams and rivers. Such land is flooded every spring and frequently is wet or water-logged all summer long. Back from the streams a short distance are short steep slopes of former streams that flowed in this land type area. The upland terraces comprise soils that are sandy in texture and relatively unproductive. Locally, areas so covered with stone and boulders occur that cultivation has not been attempted. This combination of wet land, local steep slopes and unproductive land will probably act in the future to prevent much of an increase in tillable land in this area.

The Stockbridge land type (No. 15) is composed of such a mixture of low producing soils, wet difficult to drain muck swamps and local steep slopes that it is not difficult to see why only 58 per cent of the land was tillable in 1948. ⁰ In a large number of farms in the area, a much smaller per cent than this is farmed. If individual farms on the land type are studied, the great diversity in land use from farm to farm can be seen. One farm may have 80 per cent of the land in muck that has been drained and tillable, the next farm down the road may consist of 10 per cent muck and 90 per cent Coloma and Plainfield sand. The first farm may be prosperous and well kept, and the second run down with broken down fences and dilapidated buildings. On other land types in the study, one can expect on individual farms to see some resemblance between the average of tillable land on the farms and the average for the land type. On the Stockbridge type there is seldom a farm that corresponds to the land type average.

During the depression of the thirties, much of the land was repossessed by the state for non-payment of taxes. If a farm had enough productive land to pay the taxes and maintain the family, the farm did not revert to the state. After the depression, the State went into areas of Stockbridge land and purchased farms for state game areas. The effort involved in breaking up farms so as to sell the poor land to the state and keeping the productive land in agriculture was apparently too great, because only in a few instances was this done. It appears probable that if some other system of land description were used than the rectangular system that much of this land would have never been taken into the boundaries of farms in the first place. On those farms that have developed a farming system to take advantage of whatever kinds of land they happen to possess it seems unlikely that the per cent of tillable land will be increased much.

The Leslie type (No. 11) comprises land that varies from gently undulating to quite strongly rolling. Slopes are long and locally may exceed 15 per cent in gradient. The more common gradient is 6 to 8 per cent. Locally the land may be stoney and cobbly. Frequent inclusions of less productive soil occur within the land type. Broad drainage valleys of low lying sandy soil are common. In the more rolling areas of the land type it is steepness of slope that prevents cultivation. On the undulating areas the broad swales of wet land are the limiting factor. Woodlots commonly occur on the hilltops of this land and on the wet swamps of the lowlands. It appears likely that in time considerable of the low wet land will be cultivated but probably the steep slopes will remain untillable.

Size of Farm

Farm size is an aspect of land use that differs from one natural land type to another. Table VI shows the average size of farm and average acres of tillable land per farm on the land types under consideration. The smallest average size of farm occurs on the DuPlain type (No. 31) with 97.3 acres of land. This type also has the smallest number of tillable acres per farm with 73.0 acres. The largest farms both in total acres and tillable acres occur on the Leslie type (No. 11) with 132.1 total acres and 89.0 tillable acres on the average farm. The remaining land types fall between these extremes. The greatest difference in total acres between any two land types is 34.8 acres. The greatest difference in tillable acres between any two types is less than half that of total acres, 16.0 acres. It would appear from this that farmers attempt to purchase a rather definite number of tillable acres to farm. In order to obtain this number of tillable acres, the size of farm will vary from one land type to another. There is, however, a considerable difference between land types in the acres of tillable land per farm. This difference cannot be explained from such simple statistics as these. The difference is very probably due to changes in types of farming and quality of farmer from one land type to another. This relationship is not a clear one, however.

Table VII gives a breakdown of the percentage of each of several farm size on the various land types. A general characteristic on all land types is the high proportion of 71-90 acre farms. On the average, about $\frac{1}{3}$ of the farms are in this group. Most of these farms are 80 acre farms. The next important group is the 111-130 acre farms, most of

TABLE VI

SIZE OF FARM BY NATURAL LAND TYPE

	Roxand	Riley	DuPlain	Stockbridge	Leslie
Average size of farm in acres	107.9	99.4	97.3	128.9	132.1
Average crop land in acres	84.5	75.2	73.0	74.3	89.0

TABLE VII

PER CENT DISTRIBUTION OF FARM SIZE BY NATURAL LAND TYPE (P. M. A. DATA)

Acres	Roxand	Riley	DuPlain	Stockbridge	Leslie
31-50	12.5	14.6	20.0	14.7	9.8
51-70	7.3	7.7	5.0	10.0	6.5
71-90	36.0	33.2	38.0	25.1	17.0
91-110	9.0	10.7	12.0	7.1	11.1
111-130	12.8	13.6	5.0	14.7	16.3
131-150	3.1	2.8	1.0	4.7	6.5
151-170	5.8	7.9	9.0	4.3	7.8
171-190	2.8	2.8	2.0	3.3	5.2
Over 190	<u>10.7</u>	<u>6.6</u>	<u>8.0</u>	<u>15.6</u>	<u>19.6</u>
Total	100.0	100.0	100.0	100.0	100.0
Per cent under 130	77.6	79.8	80.0	71.6	60.7

which are 120 acre farms. Third are the 31-50 acre farms, mostly 40 acres in size. The high proportion of small farms on all land types is evident when it is seen that on the various types, the percentages of farms less than 130 acres in size are: Roxand - 77.6%; Riley - 79.8%; DuPlain - 80%; Stockbridge - 71.6% and Leslie - 60.7%. About half the farms on all land types are less than 80 acres in size.

The small size of farm is even more evident if it is observed that in calculating the percentage figures, all farms less than 30 acres in size were eliminated. It was felt that farms less than 30 acres in size were part-time farms and were omitted for this reason.

There was a sizeable proportion of farms larger than 190 acres on only two of the natural land types, Stockbridge and Leslie (Nos. 15 and 11). These types had 15.6% and 19.6% respectively of farms greater than 190 acres. It might be said that on theoretical grounds Stockbridge type should have larger farms than the Riley type. The less productive soil would be expected to have larger farms. But when it is observed that the Leslie type has a greater percentage of large farms with its more productive land than the Stockbridge type, this argument seems to have little basis. Undoubtedly there is a reason for the distribution of farm sizes but this reason is not at all evident in the statistics. In the theory section of this study, some light may be thrown on this problem of farm size.

Farming Patterns

The areal distribution of farms by land types is given in Figure 14 to indicate that no particular pattern of farms exists on any land type

FARM PATTERN BY NATURAL LAND TYPE

ROXAND TYPE

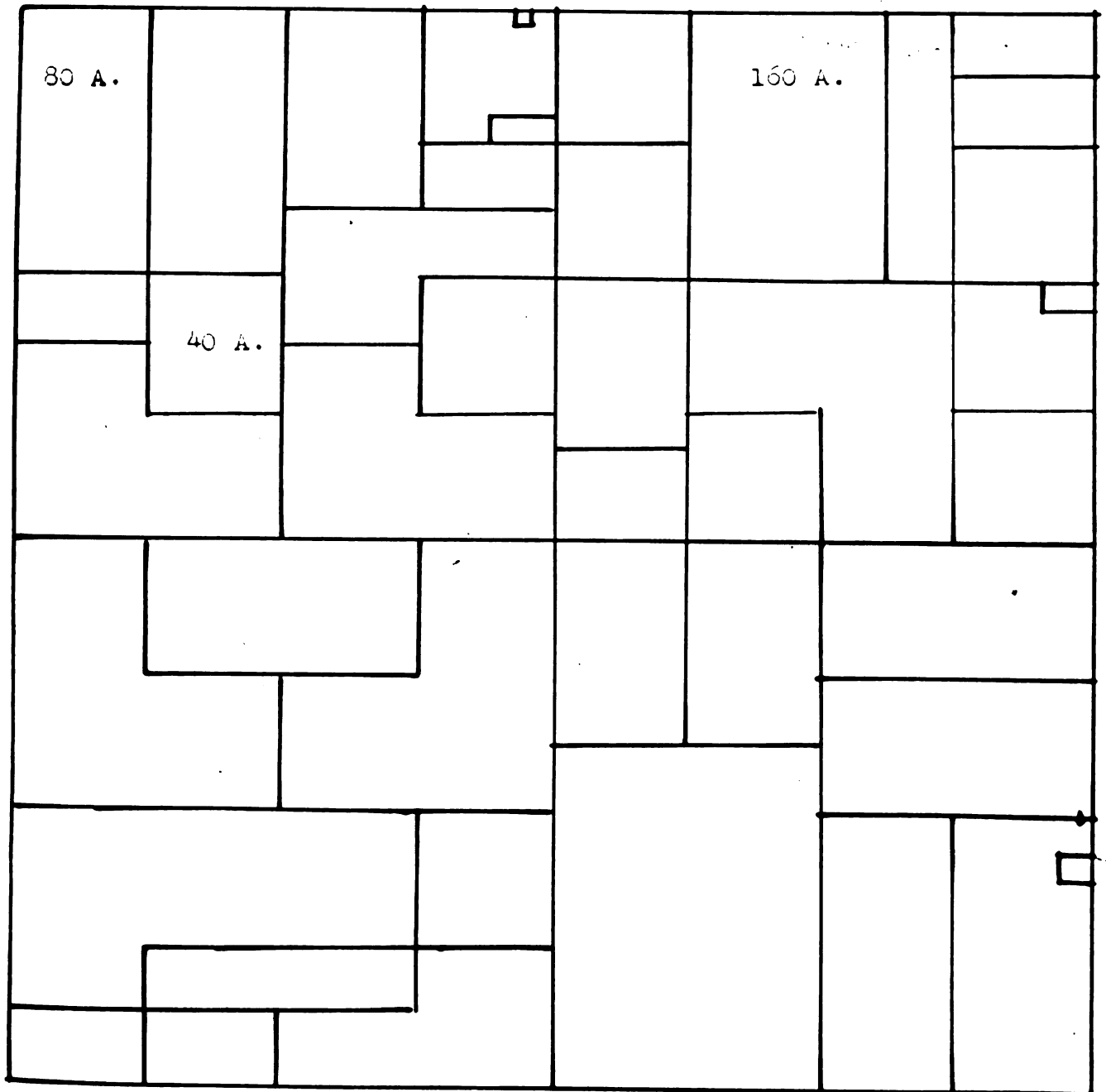


FIGURE 14
FARM PATTERN BY NATURAL LAND TYPE
RILEY TYPE

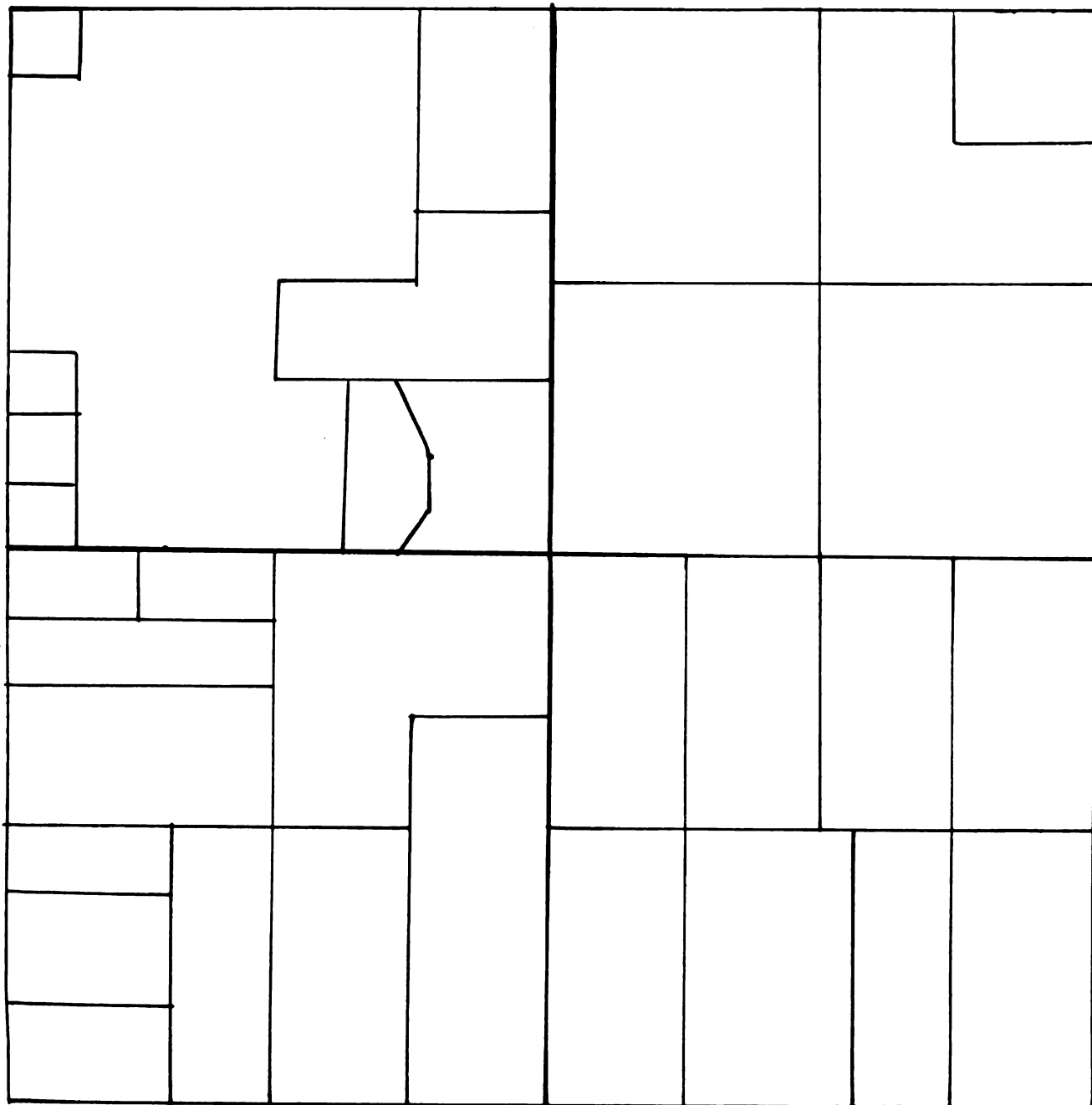


FIGURE 14
FARM PATTERN BY NATURAL LAND TYPE
DUPLAIN TYPE

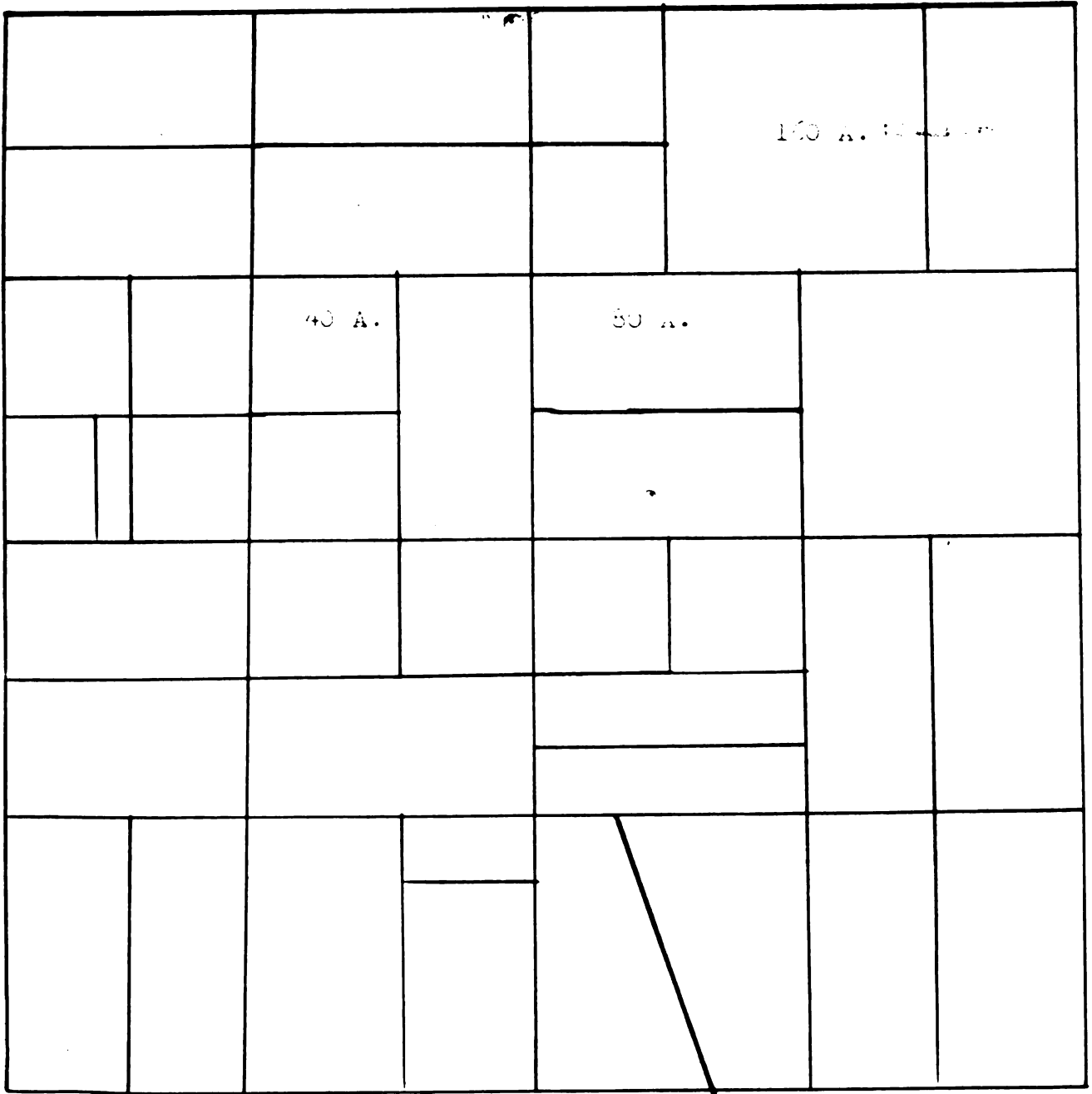


FIGURE 14
FARM PATTERN BY NATURAL LAND TYPE
STOCKBRIDGE TYPE

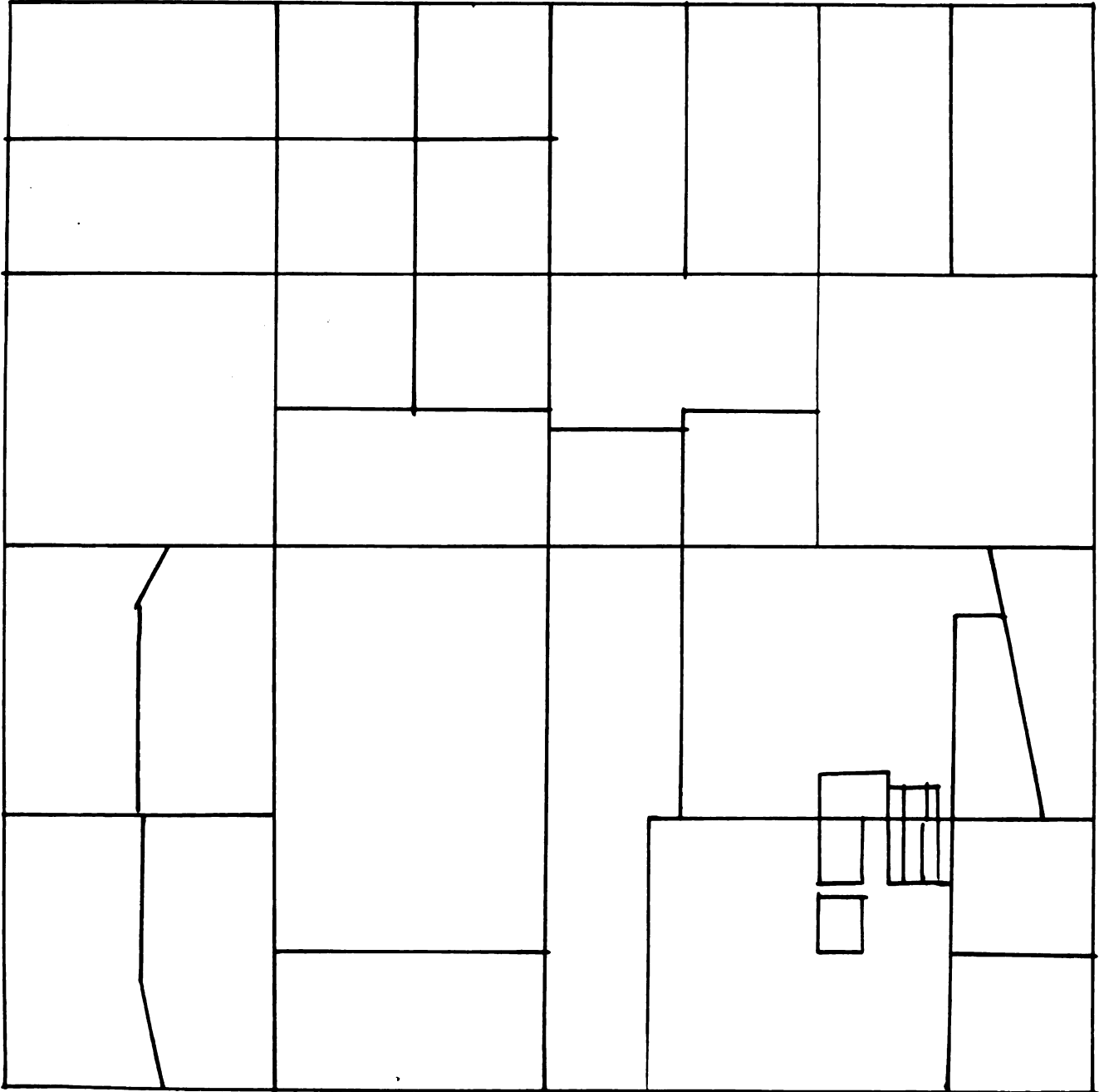
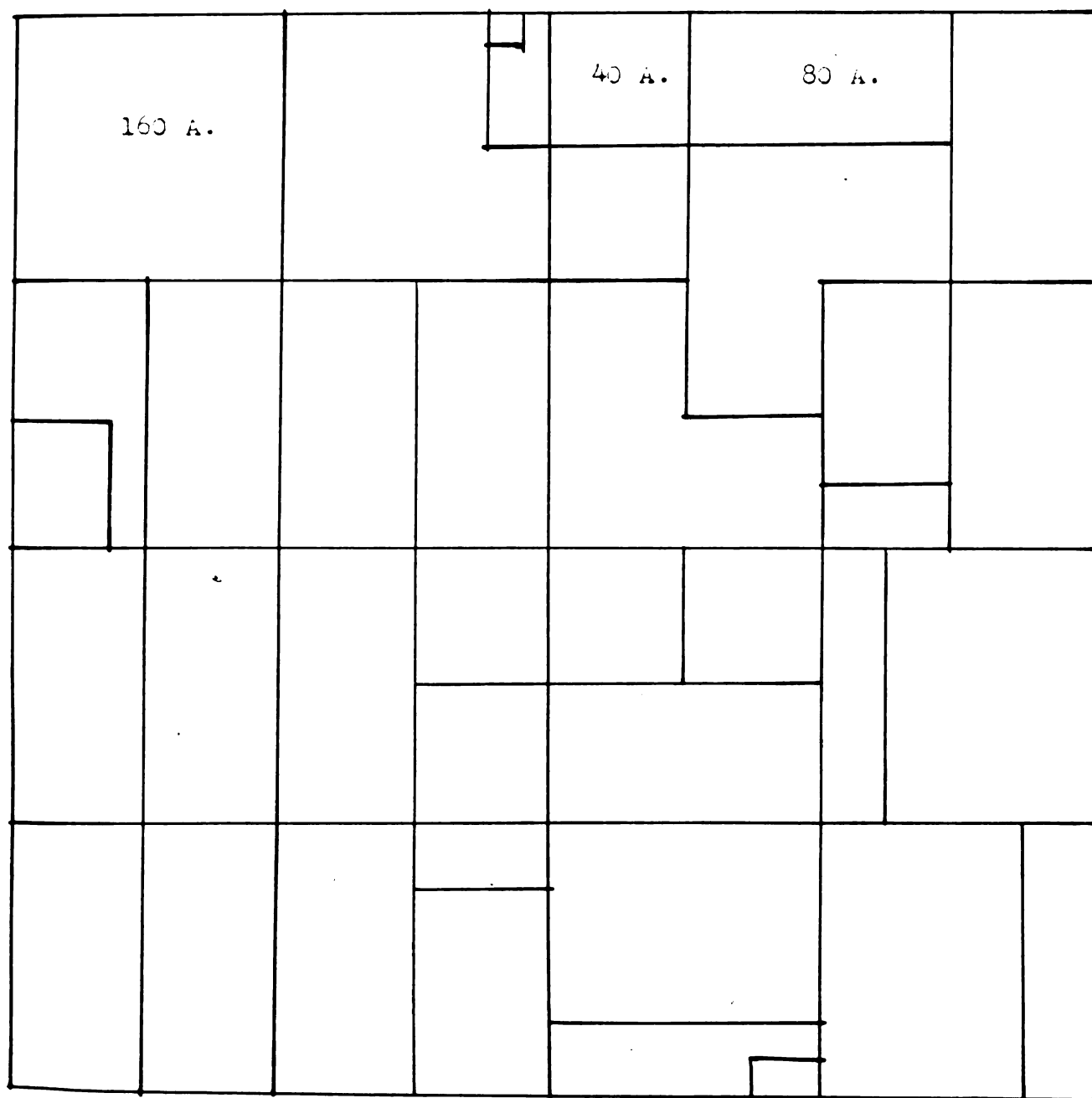


FIGURE 14

FARM PATTERN BY NATURAL LAND TYPE

LESLIE TYPE



area (28). The pattern is apparently randomly determined. Farm boundaries and size are found to be a function of the land description system set up for the Northwest Territory under the Ordinance of 1787. Square and rectangular farms are the rule because of the way in which land was laid out and sold under the ordinance.

Figure 15 gives the field pattern on an average 80 acre farm for each of these land types. Surface configuration and wet land patterns apparently alter field arrangements on the Stockbridge type only. Square to rectangular fields are the rule wherever conditions permit. It can be stated as a generality, however, that field pattern was more affected by natural land character than was farm pattern (28).

Figure 16 gives the woodlot distribution on the land types (2). It can be seen that a greater proportion of the Stockbridge and Leslie types are in woods than the remaining three natural land types.

If the woodlot distribution map could have been made on a larger scale, it would have been evident that wherever flat land occurred, the woodlots occurred mainly on the wet lands, and there only away from the roads. In north Eaton County, in Roxand and Sunfield townships in some areas it is almost impossible to find a woodlot lying adjacent to a road. Apparently farmers cleared the land closest to the road first because their houses were located by the roads. It required less time and effort to work the land close to the buildings than the land farther away.

On the rolling land, the pattern of woodlots is more closely associated with rough hilly land and wet undrained land. This is true of Leslie, Riley and Stockbridge types. Even here, there appears to have been a tendency to clear that land closest to the roads first.

FIGURE 15
FIELD PATTERN BY NATURAL LAND TYPE
ON A TYPICAL 80 ACRE FARM
ROXAND TYPE

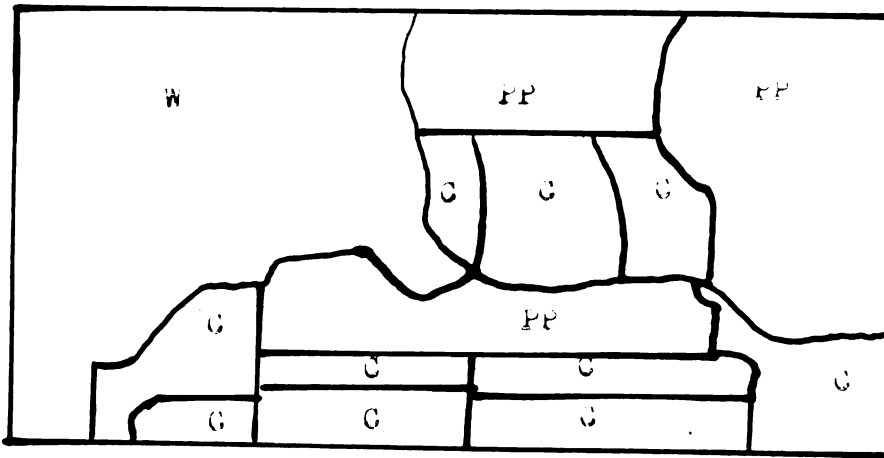
C	PP	C
C		C
C	C	
C	C	W

C--Cropland
 PP--Permanent pasture
 W--Woodland

RILEY TYPE

C	C	PP	C
C	C	W	C
		PF	C

FIGURE 15
FIELD PATTERN BY NATURAL LAND TYPE
ON A TYPICAL 80 ACRE FARM OF
STOCKBRIDGE TYPE



C--Cropland
 PP--Permanent pasture
 W--Woods

DUPLAIN TYPE

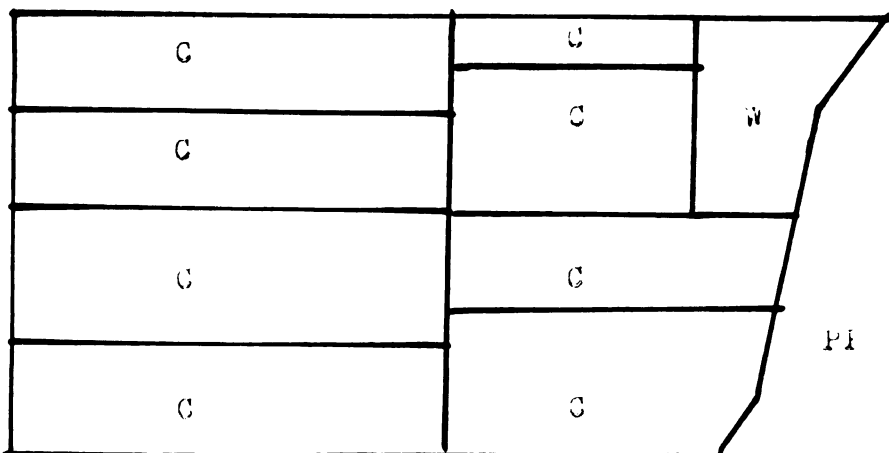
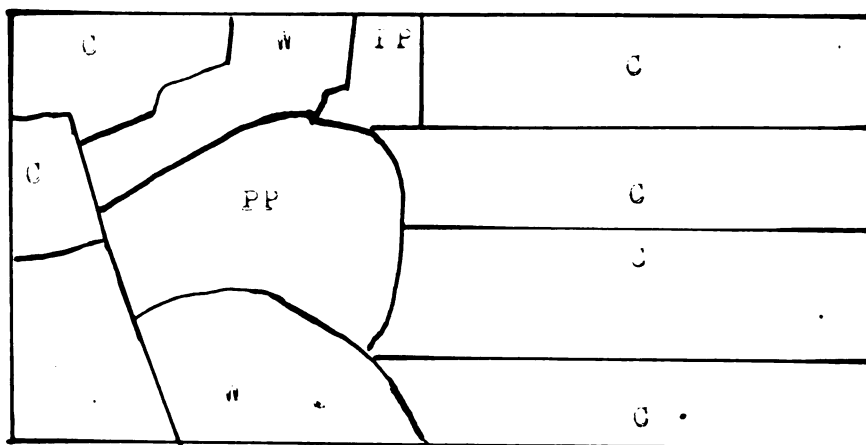


FIGURE 15
FIELD PATTERN BY NATURAL LAND TYPE
ON A TYPICAL 80 ACRE FARM OF
LESLIE TYPE

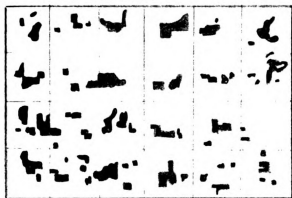


C--Cropland
PP--Permanent pasture
W-- Woods

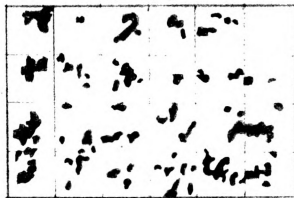
FIGURE 16

WOODLOT DISTRIBUTION BY NATURAL LAND TYPE

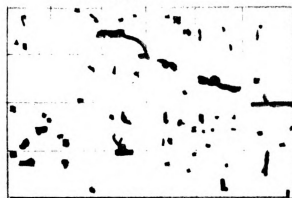
ROXAND



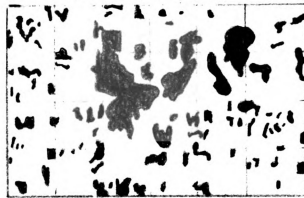
RILEY



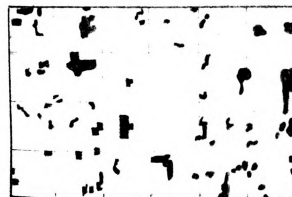
DUPLAIN



STOCK BRIDGE



LESLIE



SCALE 1/2 INCH = 1 MILE

Tillable Land Use

The per cent of tillable land devoted to any crop grown in an area is determined by the per cent of farmers growing the crop and the number of acres of the crop grown per farm. Attention is drawn to this relationship because it points out the two decisions made by farmers which cause land to be devoted to a certain crop within an area. (The first decision is to grow the crop, the second, how much of it to grow.)

It is possible for various combinations of these factors to cause perhaps 50% of the land within an area to be devoted to corn. For example, if all farms were of equal size, half the farms in any one year might devote 100% of their land to corn and the other half grow none, so that 50% of the land area in all farms would be in corn. Another combination producing the same result would be for all farms to devote 50% of their land to corn. Numerous such arrangements could be listed.

Table VIII gives the per cent of farmers reporting the various crops in 1948 by the selected natural land types. Wheat, corn and oats were reported as the crops grown on the greatest percentage of farms on all land types. If the per cent of farms growing any kind of tame hay could have been obtained, it probably would have been reported on as great or greater per cent of farms than corn, oats and wheat. As it was, there was no way of knowing, of the farms reporting alfalfa, red clover and other tame hay, which farms grew two or more kinds of hay.

It is clear that the dominant type of farming is centered around the production of the staple feed crops, oats, corn and hay and the cash crop, wheat.

TABLE VIII

PERCENTAGE OF FARMS REPORTING VARIOUS CROPS (P. M. A. DATA)

	Roxand	Riley	DuPlain	Stockbridge	Leslie
Wheat	92.9	88.9	78.0	66.8	84.4
Corn for grain	89.5	85.3	86.0	78.3	87.5
Silage corn	19.0	23.1	21.0	25.3	20.6
Soybeans	4.8	.5	7.0	1.8	
Potatoes	1.4	1.2	2.0	4.6	5.6
Dry beans	28.2	19.9	9.0	7.8	5.6
Sugar beets	3.7	2.2	7.0	1.4	
Oats	85.4	83.5	75.0	66.8	81.9
Barley	3.4	4.9	7.0	.5	1.9
Rye	1.4	2.9	14.0	6.0	5.0
Vegetables	.7	4.7	3.0	6.5	3.8
Other cash crops	5.8	1.7	3.0	12.9	1.9
Alfalfa	38.1	44.5	45.0	49.3	53.8
Clover	48.3	61.9	47.0	66.8	59.4
Other Tame hay	23.8	15.5	11.0	12.5	20.6
Temporary pasture	20.4	19.7	4.0	18.0	14.4
Rotation pasture	46.9	47.7	56.0	32.7	54.4
Summer fallow	11.6	12.0	12.0	15.7	6.3
Idle cropland	10.2	15.5	9.0	46.5	18.1
Green manure	2.0	2.0	1.0	3.2	2.5

The per cent of farms reporting a crop within an area is, in a measure, an indication of farmers' opinions regarding the possibility of economic success with the crop. If 100% of the farmers of an area grow wheat, it can be assumed that wheat is adapted to the land of the area and to the farming systems. If wheat were reported on only 25% of the farms, it could mean either that wheat was not adapted and that 25 per cent of the farmers had made wrong decisions, or else that it was adapted to the land but only 25 per cent of the individual farmers could use wheat in their farming systems. A measure of this latter conclusion can be determined by means of a historical study. If 25% of the farmers report wheat consistently through the years, the crop can be assumed to be adapted to all the land of the land type, but not to all the farming systems.

If the land types are compared, some comments can be made about each crop. Wheat was generally reported on all land types. Large differences existed between land types, however. Only 67 per cent of the farmers reported wheat on the Stockbridge type. This was 11 per cent less than the next lowest, the DuPlain type and 26 per cent less than the Roxand type, with 93 per cent of the farms reporting wheat. Since wheat is a cash crop in most of the Lansing region and is not necessary to the farming system, it can probably be assumed that the per cent of farms reporting the crop is a measure of true comparative advantage of the crop over others in the farming system on any individual natural land type. This comparative advantage is a function of crop adaptation to the land and the price relations of wheat to all other crops that could be grown. Although it is not shown here, study indicates that

wheat has been reported consistently on the various land types in essentially the same relationship between land types as reported here. This would indicate that wheat is better adapted to the Roxand, Riley and Leslie land types than to the DuPlain or Stockbridge types. Farmers' opinions and the yield figures available confirm this conclusion.

Most farms that reported wheat also reported corn, oats and some type of hay. A study of thirty-five farms selected at random from each land type gives the percentage figures for farms reporting all four of these crops: Roxand - 80 per cent; Riley - 83 per cent; DuPlain - 68 per cent; Stockbridge - 57 per cent and Leslie - 63 per cent. This indicates the prevalence of this general farming type of farming system on all land types.

An even more general relation on all land types is the almost perfect correlation between corn and oats reported. Practically every farm that reported corn also reported oats on all land types. The reason for this is that oats is almost the only crop that will follow corn in the crop rotation. Barley is not very well-adapted to the land types listed here and the table bears this out. It and spring wheat are the two grain crops that will follow corn. In cash crop areas, beans and sugar beets follow corn on some farms. The prevalence of this corn-oat crop sequence points out the importance of considering crop rotations rather than individual crops when attempting to explain farm crop ecology.

Such crops as soybeans, potatoes, sugar beets, barley, rye, vegetable crops and other cash crops are reported on such a small per cent of the farms that irrational behaviour of farmers rather than ^aany particular adaptability of the land for the crops might explain their presence.

Even with these crops there are differences between land types, however, that lead to the modification of this conclusion. If sugar beets are taken as an example, it can be seen that on the DuPlain type of land, 7.0 per cent of the farmers reported the crop. On the Leslie type, no sugar beets were reported, even though a market for sugar beets existed in the area where this type land was located. Apparently there were no farmers willing to grow sugar beets, indicating that irrationality among farmers extends only so far in explaining crop incidence.

The per cent of farms reporting ensilage corn, rotation pasture and temporary pasture measures in a rough way the presence of livestock enterprises. It is unfortunate that livestock information was unavailable from PMA data. The picture can be pieced together with the figures on these crops in addition to the information given about the corn-oats-wheat-hay relationship. All in all, there seems to be no great amount of difference between land types in the per cent farms reporting livestock. From the study of individual farms on the land types, it was discovered that the Roxand and DuPlain types had more cash crop farms than the other three types. The Riley and Leslie types had the most dairy-general farms and the Stockbridge type had more of a dairy-specialized crop type of agriculture.

The decision made by a farmer after he decides to grow a crop is how much he shall grow. This is presented in Table IX. The acres grown on any farm is determined by at least two considerations: the size of the farm and the relative importance of that crop in the farming system. The acres per farm resulting from each of these two forces cannot be determined from this table. The size of farm factor was eliminated to

TABLE IX

ACRES PER FARM REPORTING VARIOUS CROPS (FROM P. M. A. DATA)

	Roxand	Riley	DuPlain	Stockbridge	Leslie
Wheat	21.3	20.5	18.7	15.7	20.9
Corn for grain	17.3	13.7	15.9	14.7	17.9
Silage corn	9.1	8.9	8.7	9.9	10.1
Soybeans	8.6	28.0	7.4	5.6	----
Potatoes	5.5	3.4	3.5	2.3	9.1
Dry beans	13.8	12.8	8.3	8.9	9.8
Sugar beets	8.4	12.8	7.4	4.0	----
Oats	15.6	13.2	15.0	14.1	15.5
Barley	11.7	9.9	10.7	3.0	7.7
Rye	9.8	8.2	10.9	7.1	7.2
Vegetables	8.0	3.7	8.3	6.4	4.3
Other cash crops	6.7	18.0	12.7	17.1	8.0
Alfalfa	14.7	11.7	11.6	13.4	18.0
Clover	13.1	14.3	14.8	12.3	15.2
Other tame hay	13.4	9.1	22.6	11.1	12.7
Temporary pasture	16.7	10.6	9.3	13.6	13.6
Rotation pasture	16.1	14.8	15.7	21.0	32.6
Summer Fallow	11.3	11.4	11.7	9.3	16.7
Idle Cropland	9.8	11.9	14.4	17.4	18.1
Green Manure	9.5	11.9	24.0	21.4	14.5

study further the relative importance of the various crops in the farming system. The conclusion from this study was that generally, the size of farm affected only the acres of crops grown without affecting the ratio between crops until a small farm size was reached. On farms smaller than about 60 acres less individual crops were grown with a relatively larger per cent of the farm devoted to each crop.

Table X, the per cent of tillable land in the various tilled crops, presents an integrated picture of the per cent of farms reporting various crops and the average acres of the crops grown on the farms reporting them. This table provides an over-all view of the use of tillable land but is not a very useful tool for analysis. Changes in land use from year to year on the natural land types could be used in a statistical study of the elasticity of supply of crops. In this way aggregate pictures such as this could be used. While not a very good tool for analyzing land use, this table does show the resultant of all the interacting factors producing land use.

Historical study bears out that this picture is to a great part, the function of the natural land type. While land use may vary on any one land type from year to year, the differences between the types persist. In reconnaissance studies of the census extending back to 1880, the author found that more wheat was grown on the Riley and Leslie types than on the Stockbridge type. It is through experience of many years that farmers of the Lansing Region have come to recognize that only certain land types are good land for beans or corn, sugar beets or peppermint.

This thesis set out to prove whether land use varies by natural land type. This table provides the evidence for tillable land. It should be

TABLE X

PERCENTAGE OF TILLABLE LAND IN VARIOUS CROPS (P. M. A. DATA)

	Roxand	Riley	DuPlain	Stockbridge	Leslie
Wheat	23.4	24.2	20.9	14.0	19.8
Corn for grain	18.2	15.4	18.7	15.5	17.5
Silage corn	2.0	2.7	2.5	3.3	2.3
Soybeans	.4	.1	.7	.1	
Potatoes	.0	.0	.1	.1	.5
Dry beans	4.6	3.3	1.0	.9	.0
Sugar beets	.3	.3	.7	.0	
Oats	15.7	14.6	15.4	12.6	14.2
Barley	.4	.6	1.0	.0	.1
Rye	.1	.3	2.0	.5	.4
Vegetables	.0	.2	.3	.5	.1
Other cash crops	.4	.4	.5	2.9	.1
Alfalfa	6.6	6.9	7.1	8.8	10.8
Clover	7.4	11.7	9.5	11.0	10.1
Other tame hay	3.7	1.8	3.4	2.6	2.9
Temporary pasture	4.0	2.7	.5	3.2	2.2
Rotation pasture	8.9	9.3	12.0	9.2	12.8
Summer fallow	1.5	1.8	1.9	1.9	1.1
Idle cropland	1.1	2.4	1.7	10.8	3.2
Green manure	.2	.3	.3	.9	.3
Number of farms	294	407	100	217	160

stated that a difference between any two percentage figures as small as 1.5 per cent mathematically is a highly significant difference, with the sample sizes used and for percentage figures between 10 and 30 per cent. It is seen that the per cent of wheat grown on the Stockbridge type in 1948 differed significantly from the Leslie and DuPlain types which in turn differed significantly from the Roxand and Riley land types.

To take a specific example, the Stockbridge type had significantly less land than the Roxand type devoted to wheat, corn for grain, dry beans and oats. It had significantly more land in other cash crops (mainly peppermint and spearmint), alfalfa, clover and idle cropland. There was no significant difference existing in the other crops grown.

When analogous comparisons were made between all combinations of land types taken two at a time, it was found that the two land types which were most nearly alike (Roxand and Riley) varied significantly in at least three crops grown. The two land types varying most (Roxand and Stockbridge) showed significant differences in seven crops grown.

In previous studies in Michigan (17), (38), the Roxand and Riley types have been consolidated along with several other land types into a land group called Class 1 land. While the information given here shows that there is some basis for this classification, a better characterization of use could have been made if the natural land type system had been used to stratify land differences.

A summary of tillable land use is shown on Table XI. Here the twenty crops grown have been grouped into six classes of crops: corn, small grain, tame hay, plowed pasture, cash crops and other crops. Here again a difference of slightly less than 1.5 per cent is a highly

TABLE XI

PER CENT OF TILLABLE LAND BY CROP GROUPINGS
ON SELECTED NATURAL LAND TYPES

	Roxand	Riley	DuPlain	Stockbridge	Leslie
Number of Farms Sampled	294	407	100	217	160
Corn	20.3	18.2	21.2	18.9	19.9
Small grain	39.8	39.8	38.6	27.3	34.6
Tame hay	17.8	20.5	20.0	22.5	23.9
Plowed pasture	12.9	12.1	12.5	12.5	15.0
Cash crops	6.0	4.6	3.4	4.8	1.5
Other crops	2.9	4.5	4.0	13.7	4.8
Average acres per farm	107.9	99.4	97.3	128.8	132.1
Average acres cropland	84.5	75.1	73.0	74.3	89.0

significant difference in use, employing the method of the least significant difference between percentages. After comparing all land types as before (two at a time), the following observations can be made:

The Roxand type differs from the Riley in the per cent of land in corn, tame hay, cash crops and other crops. Roxand differs from DuPlain in the per cent of tame hay, cash crops and other crops grown. Roxand and Stockbridge differ in corn, small grain, tame hay, cash crops and other crops. Finally, the Roxand type differs from Leslie in the use of its land for all classes of crops given but corn.

Other combinations are: Riley and DuPlain which differ in the per cent of corn grown, Riley and Stockbridge which have differences in corn and tame hay only and Riley and Leslie which differ in small grain, tame hay and cash crops.

DuPlain differs from Stockbridge type in corn, small grain, tame hay and other crops; from Leslie in small grain, tame hay, cash crops and plowed pasture.

The final comparison is between Stockbridge and the Leslie types. These types differ significantly in the per cent of small grain, cash crops, plowed pasture and other crops.

All these combinations are given to indicate that even with a crop classification as general as given here, that tillable land use varies significantly from one land type to another, in at least one class of crop.

From this table, it can be observed that corn, for example, appears to be a crop more adaptable to all land types studied than the small grains. There was a difference of 3 per cent between Riley and DuPlain

in the per cent of tillable land in corn. At the same time differences in small grain were as great as 12 per cent between Riley and Stockbridge land. The per cent of land in other crops varied almost as much between individual land types as did small grains. The Stockbridge type had almost 11 per cent more tillable land in this class than the Roxand land type. This class of tillable land consists mainly of idle land.

Effect of Farm Size on Tillable Land Use

In the above section it was seen that land use varied by land type. Why it varied was not explained. This problem will be taken up here.

It was seen in a previous section that size of farm varied significantly from one land type to another. It was also found to be true that land use varied by land type. The question which now arises is whether the difference between land types in land use is due to a difference in size of farm.

This question was studied first on 94 farms of the Riley land type in Ingham County to discover how much change in land use resulted from a change in size of farm. Table XII gives the per cent of land devoted to six classes of crops for all 94 farms, for 17 small farms less than 50 acres in size, for 17 large farms of more than 190 acres and for 24 eighty acre farms.

The conclusions that can be drawn are these: as farm size decreases, the per cent of tillable land increases, the per cent of land in small grain increases and the per cent of land in tame hay decreases. Cash crops are almost absent on the farms smaller than 50 acres.

TABLE XII

TILLABLE LAND USE IN PER CENT FOR DIFFERENT-SIZED FARMS
ON RILEY LAND TYPE IN INGHAM COUNTY

	All farms	17 farms under 50 acres	24 farms of 80 acres	17 farms over 190 acres
Corn	18.3	18.7	14.4	21.0
Small grain	40.0	50.6	40.9	37.2
Tame hay	20.8	17.2	19.4	21.3
Plowed pasture	9.3	9.3	7.8	9.7
Cash crops	5.1	.2	6.5	6.0
Other crops	6.2	3.8	10.8	4.7
Average acres per farm	100.6	28.4	80.0	221.7
Average tillable acres per farm	74.4	23.2	60.9	159.9
Per cent tillable land	74.0	82.0	76.1	71.3

Table XIII is an extension of the idea just developed, but for three land types. Here comparisons of land use are made of 80- and 160-acre farms on each of the three land types.

The same relationships mentioned for the Riley land type farms from Ingham county were found to be true for Roxand, Riley and Stockbridge types in Table XIII for the entire region. It can be generally concluded that although land use does vary by size of farm on the same land type that for the same size of farm on different land types, land use differences vary significantly. Using only 80 acre farms, a comparison can be given to show the following: land in corn varied from 20 per cent on Roxand type to 15 per cent on Riley land; small grains from 29 to 39 per cent respectively on those two types; hay from 20 to 24 per cent; cash crops from 2.8 to 5.6 per cent; plowed pasture from 8.7 to 14.5 per cent and other crops from 3.6 to 17.9 per cent.

If further stratification of the statistics could be made, factors such as age of farmer, tenancy grouping and type of farming could be isolated and tested for their effects on land use. The information for such division of land use data was not available for use in this study. Thus the short discussion of the effect of size of farm on land use on a given land type can be taken as an example of a method for the study of the effect of any factor on land use. Studying the relation of a factor to land use still does not answer the more fundamental question of what causes the particular factor to be as it is. For example, size of farms within a land type is a factor affecting land use, but the question remains of what causes the farms to have the particular sizes they do. This study of cause and effect cannot be answered in this section. The problem will be discussed in Part II under the land use theory sections.

TABLE XIII

TILLABLE LAND USE BY FARM SIZE ON THREE NATURAL LAND TYPES

Land Farm Type Size		Roxand	Riley	Stockbridge
Corn	80-acre farms	19.7	14.9	17.4
	Large farms	21.1	20.7	21.6
Small grain	S	38.2	38.8	29.3
	M	38.9	39.0	29.1
Hay	S	20.8	20.3	23.9
	L	17.6	19.3	23.7
Cash crops	S	5.6	4.9	2.7
	L	5.4	4.7	2.2
Pasture	S	12.0	14.5	8.6
	L	13.1	13.9	12.0
Other land	S	3.5	6.5	17.9
	L	3.6	2.2	11.1
Acres in farm	S	80.0	80.0	80.0
	L	220.9	195.1	214.8
Acres in crops	S	63.7	63.2	51.7
	L	166.9	149.7	126.2
Per cent land tillable	S	79.7	79.0	64.6
	L	75.5	76.7	58.7

INTENSITY OF LAND USE

General Discussion

Von Thunen (41) has given the basis for the belief that intensity of land use should vary with distance from market. Krymowski^z (22), making further study of Von Thunen's conclusions, has shown that intensity of use should vary also with the productivity of land. Thaden (32) in his excellent study of the Lansing region demonstrated that use intensity varied with the distance from Lansing in 1930. This has been shown in other studies (6), (10), thus it can be taken as a demonstrated fact. No figures relating to intensity of use with distance from town are included in this study for that reason.

Brinkman (6) has stated that soil productivity differences often exerts a stronger influence on intensity than the distance from market. He was careful to point out, however, that this influence of soil differences became relatively more important as distance from market decreased. This being the case, the greatest differences in land use between land types should occur close to market.

Intensity By Land Type

The sample farms for this study were taken on an average of about fifteen miles from Lansing. It is possible that there may not have been full opportunity for influences from the market to be asserted in land use intensity on the various land types. Furthermore, it is probable that the intensity measures employed, may not have been the best measures to use. Table XIV gives the measures that were used with the resulting intensity figures. Data for this table were secured from the Minor Civil

Divisions tables of the 1945 Census of Agriculture for selected townships by natural land type (36). Comparative data are given from farm accounting farm records of the Agricultural Economics Department of Michigan State College (25).

It appears from both the census and farm accounting records that intensity, as measured by the number of animal units and productive days of work, varies from one land type to another. There appears to be about one more animal unit per 100 acres of farmland on the Roxand and Leslie land types than the Riley and Stockbridge types. If tillable land is considered, the livestock intensity on the Stockbridge land type is considerably less than on the other three types. Productive days of work does not appear to vary significantly from one type to another. The differences between land types were not measured statistically for significant differences because of a lack of reliability and validity measurements for such data.

The interpretation of Table XIV is a rather precarious undertaking. In the first place, the concepts of the animal unit and the productive man work units is not as rigid and reliable a concept as one might be led to believe. In the second place, the sample farms from which the samples were drawn were not the most reliable samples that could have been taken were the data available. Reliable information was not available in the sense that samples were too small in the case of the farm accounting farm data. In the case of the census data the townships selected only approximated the natural land types they were selected to represent.

In general all the land types except the Stockbridge type probably have about the same intensity of use. If some better measures of

intensity were available for this investigation such as gross income, net income or amounts of physical output per year, the differences between land types would probably assert themselves to a greater degree.

Methods Used in Determining Intensity from the Census

The method used for determining land use intensity from census data was worked out by Mr. John Doneth of the Michigan State College Agricultural Economics Department and the author. It consisted of estimating the numbers of the various kinds of livestock per township and assigning a productive man work day factor and a productive animal unit factor to each grade of livestock. The number of animal units and productive days of work was calculated for each kind of crop according to data published by Hill and Doneth (18). The total number of animal units was calculated per township and per acre by land type. Similar calculations were made for crops. Total productive days' work per acre on crop and livestock were added together to obtain total productive days' work per acre.

As a more specific example of how this process was used, suppose it is assumed that there was listed in the census for township X, a figure of 10,000 sheep. In the next column there was listed a figure of 2000 ewes and lambs kept for breeding. Although it did not specifically state that most of the other 8000 animals were lambs, this could probably be safely assumed. To obtain the animal units of sheep in the township, the figure of 2000 sheep for breeding was multiplied by the factor .14. This figure was then added to the figure obtained by multiplying 8000 lambs by the factor .05. The number of productive animal units of sheep in township X, therefore, was found to be 280 plus 400 or a total of 680

animal units. This number of animal units was added to the number for all other kinds of animals kept to determine the total number of animal units in the township. Although this method appears to measure intensity rather well, the specific reliability of the method needs further investigation.

The Use of Census as a Measure of Land Use by Land Type

One of the reasons that the natural land type was selected instead of soil type for this study was that it was felt that census data might be used as a measurement of land use by land type. In the scale of mapping used by Veatch (39) for delineating natural land types of Michigan, it was possible on many of the more extensive types to find that entire townships were covered by one natural land type. This would never be possible in the case of the soil type. If a land type completely covered several townships in its occurrence throughout an area of several counties, it should be possible by the use of township data to characterize land use by natural land type. Thus, if several township samples of land types could be found, it would be possible to measure the differences in land use by land type.

The idea was tested by selecting four groups of townships to correspond to natural land types 1, 2, 4 and 5. Table XV shows land use by land type obtained from the census data. P. M. A. data were not available for 1944, the year on which the last census of agriculture was based.

A devious method of comparison was used in Table XVI to show that census data probably would agree well with P'MA figures for land use, if

TABLE XV

COMPARISON OF SELECTED TOWNSHIP LAND USE DATA FROM 1944 CENSUS
OF AGRICULTURE AND 1948 PMA LAND USE DATA

Source of Data	Roxand		Riley		Stockbridge		Leslie	
	1948 PMA	1944 census	1948 PMA	1944 census	1948 PMA	1944 census	1948 PMA	1944 census
<u>Crop class</u>								
Corn	20.3	20.2	18.2	19.0	18.9	19.2	19.9	15.4
Small grain	39.8	29.7	39.8	27.4	27.3	20.9	34.6	30.3
Tame hay	17.8	20.4	20.5	18.8	23.5	21.4	23.9	23.1
Plowed pasture	12.9	11.4	12.1	14.7	12.5	14.1	15.0	18.9
Cash crops	6.0	10.6	4.6	7.2	4.8	5.3	1.5	1.6
Other crops	2.9	7.5	4.5	12.7	13.7	18.7	4.8	2.7

TABLE XVI

A COMPARISON OF PMA AND CENSUS DATA BY USING A THIRD MEASURE,
AGRICULTURAL ECONOMICS DATA FROM FARM ACCOUNTING FARMS

	1944 Comparison		1948 Comparison	
	Census	Ag.Econ.	Ag.Econ.	Census
Corn	19.0	24.0	22.0	18.2
Small grain	27.4	26.0	34.0	39.8
Tame hay	18.8	20.0	20.0	20.5
Plowed pasture	14.7	17.0	16.0	12.1
Cash crops	7.2	5.0	2.0	4.6
Other crops	12.7	8.0	6.0	4.5

the two sets could have been obtained in the same year. It is seen that in the census figures for 1944 and for PMA figures in 1948, each agree fairly well in their respective years with the figures obtained on land use from an average of about 150 Farm Account farmers for Type of Farming Area 5, the area covered by the Lansing region (9). Since things equal to the same thing are equal to each other, there is at least some agreement between PMA and census data for land use studies.

There is a need for further testing of the use of census information for land use studies of a more or less broad nature. If it is found that census data are fairly reliable, then it would be possible to use the vast store of historical land use data available from the census for studies in land use trends by land types. The value of data such as these, if reliable, is obvious.

Land Valuation As a Measure of Intensity

Land use intensity is the result of a historical process. For this reason it would be well to include investments per acre over a number of years. Unfortunately, census data appears after testing to be of no help here. There is as much variation within land type as between land types. The only other source of investment figures on individual farms appears to be the tax rolls. While tax assessment figures often leave something to be desired as to accuracy, there is sufficient homogeneity of the data within land types and heterogeneity between land types to give some aid in investment studies. On four of the land types on which tax data were available, the valuation varied from a low of \$25.58 on Stockbridge land to a high of \$59.99 on Leslie type. Roxand and Riley types had valuation of \$53.67 and \$51.65 respectively (20).

Since a valuation figure on the tax roll in Michigan includes the total valuation of land and buildings for the farm, there is no way of knowing the valuation of land as separate from buildings. From observation it appeared that quality of buildings followed the same trend as tax valuation per acre. Land Type 3 that was not included in this survey of valuations probably would fall next to the bottom in both valuation and quality of buildings.

Land Productivity by Land Type

The aim of the whole study included here was to study use and not productivity. Since, however, land use is partially a function of soil productivity, it was considered that the inclusion of such soil productivity figures as were available would be proper. It should be stated here that such figures as could be found are probably not as accurate as the estimates that could and have been made by experienced agronomists. It is regrettable that there are not more soil productivity figures available by either land type or soil type on which to base such studies as this. Unfortunately it is impossible to characterize yields by soil type in less than eight or ten years of study.

Productivity figures were taken from three sources for the land types. Census figures for three census periods comprised one estimate (36). Figures from the records of Soil Science Department experimental fields comprised another (31) and the third source was from the Farm Accounting farms of the area (25). Table XVII gives an estimate of the yields of the major crops by land type from each of the three sources.

TABLE XVII

SOIL PRODUCTIVITY ON FOUR SELECTED NATURAL LAND TYPES FROM
THREE DATA SOURCES

		Roxand	Riley	Stockbridge	Leslie
Corn for grain (Bu.)	Census	32.4	31.1	31.7	31.3
	Ag. Econ.	39.7	39.6	33.4	41.0
	Soils Dept.	47.0	42.0	36.0	37.0
Corn for silage (Tons)	Census	8.8	7.9	7.8	8.3
	Ag. Econ.	---	---	---	---
	Soils Dept.	---	---	---	---
Cats (bu)	Census	34.3	30.5	25.1	24.0
	Ag. Econ.	43.8	39.4	31.0	32.6
	Soils Dept.	61.0	56.0	43.0	44.0
Wheat (bu)	Census	22.1	21.0	18.1	18.2
	Ag. Econ.	25.8	26.1	19.1	19.2
	Soils Dept.	28.8	29.0	27.0	28.0
Alfalfa (Tons)	Census	1.5	1.4	1.3	1.5
	Ag. Econ.	1.8	1.7	1.7	1.7
	Soils Dept.	2.8	2.5	2.6	2.8
Red clover (Tons)	Census	.8	.8	.7	.8
	Ag. Econ.	---	---	---	---
	Soils Dept.	1.9	1.8	1.3	1.2

As a general productivity rating for the five land types studied, Roxand type is probably highest for cash crops and grain crops. Roxand is followed by Riley, Leslie, DuPlain and Stockbridge in that order. Hay yields seem to be best on the Leslie type.

Input-Output Relationships by Land Types

Little experimental work has been done to characterize soil types and nothing to characterize land types as to the ability to absorb inputs of labor and capital. A few fertilizer studies have been conducted by not generally at more than two levels so that efficiency curves for the use of fertilizer have not been developed. Watson (42), Smith (30) and Cook (8) have studied several soils of Michigan with fertilizer input-output studies with certain special crops. No conclusions can be drawn for the land types in this study however insofar as physical capacity or efficiency of the land is concerned.

If agricultural land use is ever to be seriously studied, there will have to be more attention given to characterizing land by its physical input-output relationships.

Changes in Land Use from Year to Year

Nowhere in this study has there been a detailed history of land use on any of the natural land types. This is because there is an almost total lack of such land use history. The P. M. A. has history running back to 1946. The census of agriculture is available for the years 1935, 1940 and 1945 by minor civil divisions. Farm accounting records are available on a few farms for the years 1929 through 1949. There are not

enough farm records available to characterize land use by years on the natural land types.

In spite of the paucity of information, something should be said about changes in land use from year to year. Table XVIII is given to provide some insight into this aspect. This table is provided to show changes in land use on representative farm-accounting farms on four natural land types by two-year periods from 1930 through 1940. The picture is given to show how land use changes over short periods on single farms. All farms selected were larger than 160 acres. Thus the opportunity was available on each farm every year to grow all the crops in a rotation.

About the only conclusion that can be drawn from the table is that land use changes considerably over short periods of time. Since only single farms are given, no land type comparisons can be made.

If the crop, tame hay, is taken as an example of how greatly land use changes, it is seen that on the Roxand farm, the land in tame hay varied from a low of 21 per cent of the tillable land in hay in 1936 and 1940 to a high of 30 per cent in 1930, a change of 9 per cent. The Riley land type farm changed 16 per cent, from a low in 1930 of 8 per cent to a high in 1932 of 24 per cent. The Stockbridge type farm changes from 21 to 48 per cent over the same period and the Leslie type from 12 to 40 per cent for changes of 27 and 28 per cent respectively.

These figures point out the difficulty of interpreting land use data for individual farms. In averages of several dozens of farms, the individuality of land use on single farms is lost. While this points out trends in use on a single land type, it frequently leads the researcher to believe that the average represents every farm on the land type.

TABLE XVIII

CHANGES IN PER CENT OF TILLABLE LAND DEVOTED TO FIVE CROPS
FROM 1930 TO 1940 ON REPRESENTATIVE FARMS*
FOR FOUR SELECTED NATURAL LAND TYPES

	1930	1932	1934	1936	1938	1940
Tame Hay						
Roxand	30	27	29	21	26	21
Riley	8	24	10	10	11	19
Stockbridge	28	21	40	21	33	48
Leslie	15	20	19	40	12	36
Plowed Pasture						
Roxand	9	15	12	28	8	9
Riley	12	10	21	10	19	10
Stockbridge	10	16	13	8	23	1
Leslie	21	8	19	7	34	8
All Corn						
Roxand	22	28	25	20	15	23
Riley	12	10	17	13	17	16
Stockbridge	31	29	26	30	17	30
Leslie	25	28	22	16	13	16
Cats						
Roxand	19	18	18	17	10	11
Riley	0	0	10	24	7	24
Stockbridge	20	23	20	21	17	10
Leslie	9	8	10	8	11	23
Wheat						
Roxand	0	0	7	0	23	4
Riley	22	20	16	17	27	13
Stockbridge	0	0	0	19	0	0
Leslie	14	14	7	21	13	11

* Michigan Farm Accounting Farm Records, Agricultural Economics Department, Michigan State College, East Lansing, Michigan, unpublished (23).

Summary of Statistical Work, Part II

Agricultural land use from a sample of almost 1300 farms or Production Marketing Administration cooperators were studied to discover differences in land use between five selected natural land types in the Lansing region of Michigan.

Within wholly agricultural areas of the land types studied, only the Stockbridge type of land had less than 99 per cent of the land in farms. Only 60 per cent of the land of this type was estimated to be in farms. The remaining 40 per cent was in idle land or state game areas.

Seventy-five per cent of the land in farms was cultivated in 1948 on the Roxand, Riley and DuPlain land types. On the Stockbridge land type only 58 per cent of the farmland was tilled and on the Leslie type, only 68 per cent was under cultivation. The non-tillable land on all land types was devoted mainly to woodland, pasture and swamps.

An analysis was made of the land tilled in 1948 on the five natural land types selected for twenty crops. Differences were discovered to exist between the land types for a considerable number of crops. The most often reported crops on all land types were corn for grain and silage, oats, wheat and tame hay.

The twenty crops studied on the five selected natural land types were grouped into six crop groups, corn, small grain, tame hay, plowed pasture, cash crops and other crops. Even with this general crop classification, differences were found to exist between all natural land types considered.

The effect of farm size on land use was studied. Land use was found to vary by size of farm. Differences in use due to size of farm were

less on any given land type than between use on the natural land types.

Intensity of agricultural land use was studied. Animal units per 100 acres of cultivated land were calculated. Productive man work days per 100 acres of farmland and per 100 acres of tillable farmland were found. The use of census information as a tool in determining land use intensity was discussed. Land valuation on the various types of land was given and discussed. Few conclusions about the intensity data were drawn because of a lack of methods for evaluating the intensity measures used.

Estimates of land productivity by land type for several crops using three sources of data ^{were} ~~was~~ included. Finally changes in land use from year to year on selected farms on four land types were given.

The major conclusion that could be drawn from Part II is that land use varies significantly from one natural land type to another. This proves the hypothesis that the natural land type concept measures differences in natural environment which within a given market environment will be reflected by differences in land use. Practically no conclusions about why land use varied between natural land types could be drawn from Part II. This was because of the lack of precise information on soil productivity and input-output relationships on the various land types.

PART III A DISCUSSION OF THE CAUSES OF DIFFERENCES IN LAND USE PATTERNS

Introduction

In the preceding sections, statistics were given for various aspects of land use on several selected natural land types of the Lansing region. The facts presented proved that land use varied from one natural land type to another. This proved the first hypothesis of the study, that differences in use were associated with differences in natural environment as measured by natural land types. The second hypothesis given was if land use did in fact differ between natural land types, that a method could be developed to explain how these could have come about. In the statistical sections where facts about existing use were presented, little if anything about the reasons for an existing use could be discovered from the data presented. In other words, the statistics were not arranged or presented in such a way that cause and effect relationships could be discovered.

To have drawn conclusions why land uses existed or how certain uses came about would necessarily have rested heavily on valuations and preconceived notions of the author. The facts are of such a nature that it is nearly impossible from observation to determine how or why land use in any particular ^{AREA} comes about.

In studies of land use employing the statistical method, there are often blank spots in the information. That is, a complete picture of land use is not presented. Inferences about reality cannot be drawn without information from which to draw them. For example, in this study, yields per acre were little better than guesses. Input-output relationships

on the land types were completely lacking and farm incomes could not even be approximated. It can readily be seen that with such lack of information, it would be virtually impossible to discover the reasons why land use differs between natural land types.

In such a complicated field of study as land utilization, it would be an aid to research if some method or framework of study could be developed to study the cause and effect relationships which exist. One such system of study is available. This system is known as the analogy. If by use of certain assumptions, a system can be developed synthetically that is logical within itself and resembles the realities of the world, the hypothesis can be made that the theoretical system developed is the one that operates within the real world. This hypothesis can be tested experimentally and statistically. After trial and error with several such theoretical systems, one can probably be found that when tested fits most of the facts of the real world. When such a system is found, rapid strides forward become possible in research techniques.

The following sections are an attempt to synthesize such a system. Only a beginning is made. If, however, only a part of the system holds when finally tested against the realities of the world, the effort will have been worthwhile.

In the synthetic method used, the assumption is made that every farmer has perfect knowledge about his land and the price system in which he operates his business. Such physical realities as vagaries of the weather, and risk and uncertainty of the economic world are ignored. Institutional factors and other irrational behavior are ignored also.

In a complete explanation of land utilization within an area, all the realities of the real world would have to be included. For a beginning explanation, however, only the more important factors affecting land use should be included to gain clarity of the land use process without undue complexity in the explanation. After a beginning hypothesis has been developed and tested, then, other assumptions and refinements can be added to the system. These additions will not invalidate the beginning structure, if it has been tested, they will only alter and refine it.

Throughout the sections on theory, one main assumption is made. This is, farmers attempt at all times to maximize profits and do this under conditions of perfect competition. A second assumption is made that only full-time farmers working on one-man farms are of any real importance in determining average farm size and land use within an area. A third assumption states that conditions of production are static and knowledge of production is perfect. Further assumptions are included in the main body of the theory.

Factors Affecting Farm Size with a Given Net Return for Labor and Management Per Acre

Choice of size of farm is an interesting phenomenon. Although it varies considerably from farming system to farming system under different states of technology, there is one characteristic that appears in much of the world's agriculture. This characteristic is the association of family with farm. One man with the help of his family operates the farm business. A notable exception to this is found in collectivist societies.

In the United States, China and most other countries the family farm is the rule.

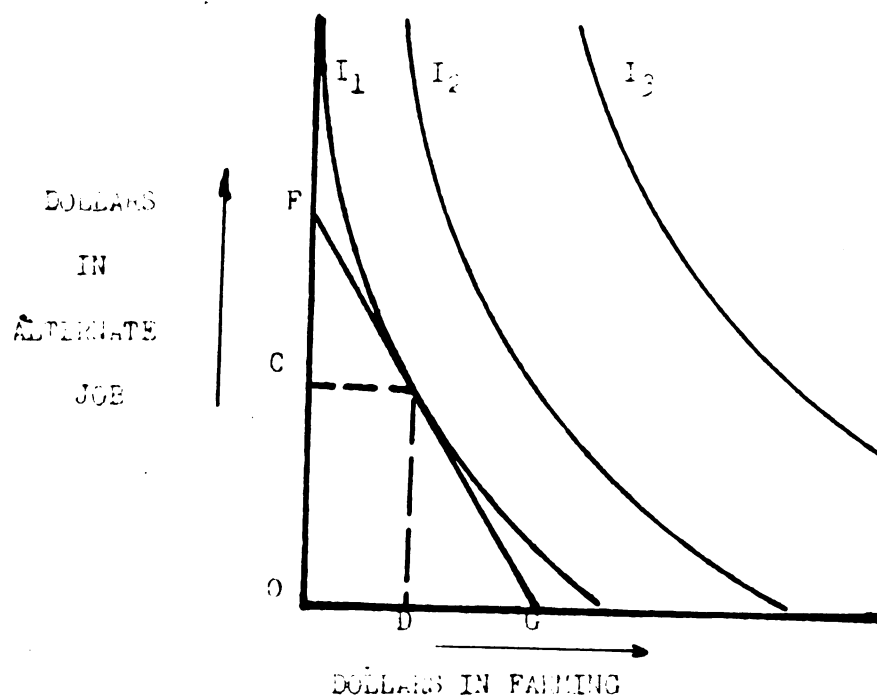
In this section only one-man farms will be considered. The factors that determine net returns for labor and management per acre will not be discussed. The problem to be considered is, with a given net expected income per acre, why does the size of farm vary so much in a given farming system area? Under a given proportion of factors of production including one man as the labor factor what will be the minimum and maximum size of farm under a given farming system?

If land use is assumed to be a rational procedure, the problem of finding the determinants of farm size in a given type of farming area can be approached with economic analysis. This rational process presupposes that farm operators attempt to maximize net profits over the long run on their farms both in the selection of farm enterprises and in their everyday farming operations. It is assumed that in the long run, economic forces of competition and ^{AL} alternative opportunities will eliminate those farmers who do not in fact maximize net returns. It is recognized that in the short run, capital rationing, various institutional factors and combinations of circumstances will often operate to sustain those operators who operate their farms at less than maximum net profit.

A fundamental reason why people farm can be shown with a system of indifference curves. Figure 17 shows an indifference map of a man faced with the decision of whether to farm or not to farm.

For example, the indifference curve I_1 shows all the combinations of dollars earned in a highest alternative occupation and dollars earned in farming to which the man would be indifferent. In other words, any

FIGURE 17
INDIFFERENCE MAP OF A MAN FACED WITH THE DECISION
TO FARM OR WORK IN AN ALTERNATE JOB



point on the curve I_1 is as satisfactory to the man as any other point. The situation presents two commodities, dollars in one job and dollars in another job, that can be purchased with labor.

Two more concepts are included in the Figure as constructed. The first is that each higher indifference curve is more desirable to reach than the previous one. I_2 is a more desired position than I_1 because of a psychological fact that most men prefer more money to less money. The second concept is that of increasing marginal disutility of labor as more work is done at any wage rate. This is shown by increasing intervals of space between indifference curves away from the origin O .

To review, each point on an indifference curve is equal in desirability to any other point on the same curve, a higher curve is to be desired over a lower one and there is an increasing physical and psychological difficulty involved in reaching each higher curve.

If a man is indifferent as to any point he may reach on any one curve but would rather reach a higher curve if he could, how does he decide what to do? Fortunately this is decided for him, not by what he wants to do but by what he can earn in each job for his labor. If the indifference curves as drawn are compared with the opportunities available, the decision is made as to the best way to spend time working between the two jobs. If FG represents the opportunities available for buying dollars by spending labor, and FG is tangent to I_2 at E , then the optimum way to spend time working is to earn OD dollars farming and OC dollars in the other job. That point E represents the point of maximum utility that can be reached with the conditions given can be explained by moving away from point E in either direction on line FG . If any other

11

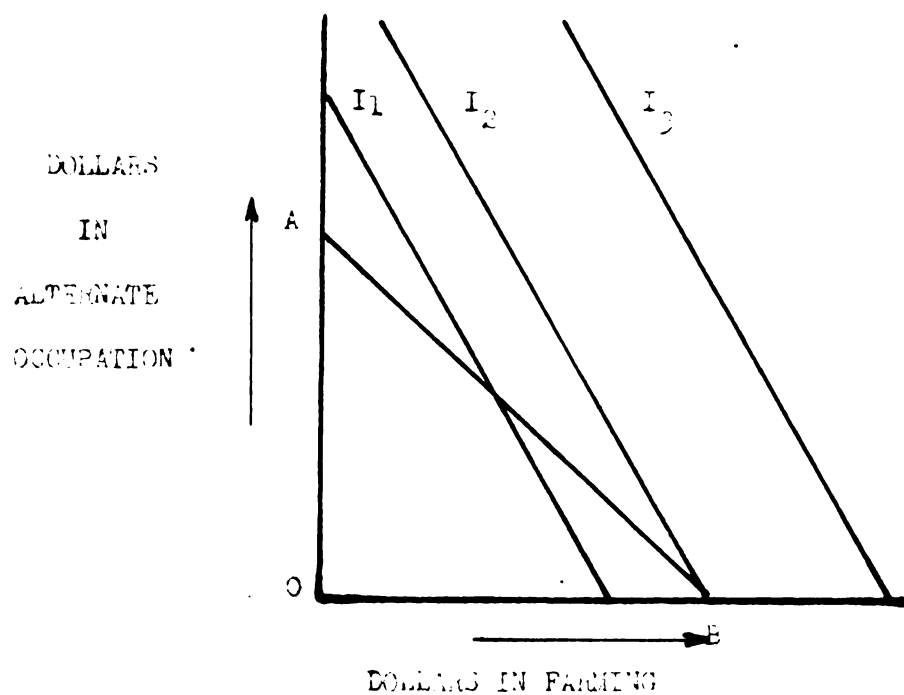
point on line FG is selected than E, a lower indifference curve will be reached and less utility for the same expenditure than at E will be received.

In the case of choosing between two occupations, the shape of the indifference curves may well be different from those drawn in Figure 17. Hicks (16) has pointed out that very probably the curves will be convex to the axes due to the principle¹⁸ of diminishing marginal substitutability. The only argument that this principle holds here is to say that a man would rather work at a variety of jobs if given free choice. This may or may not be true. Figure 18 shows an indifference map of a man drawn in such a way that for all but one condition of choice, namely, where the slope of the wage opportunity line is parallel to an indifference curve, a man will either farm full-time or work full-time in his highest alternative occupation. At the same time under the special conditions where the wage opportunity line is parallel to the indifference curve, an opportunity for part-time farming exists.

Figure 18 shows with wage opportunity line AB that touches I_2 at B that the individual for which this indifference map is drawn would rather earn zero dollars in a non-farm alternative job and OB dollars farming.

For every person farming such a decision as is discussed above is constantly before him at every change in wages in either farming or his highest alternative job and at every change in preferences, that is, his indifference curve. This idea can now be generalized to say that for all people presently farming, there are alternative occupations. The reason they are farming is that the alternative jobs are not sufficiently lucrative to induce them to change. It was conclusively shown during World

FIGURE 13
INFLUENCE MAP OF A MAN FARMER WITH THE CHOICE
OF FULL TIME FARMING OR FULL TIME WITH ANOTHER OCCUPATION



War II that many farmers would leave the farm if alternative jobs became sufficiently enticing in relation to agriculture.

The next important question to consider in studying the theory of farm size is not one of logic but of belief. Does a man work for a daily wage or a yearly wage? If he works for a daily wage, the problem is one of finding his daily supply schedule of labor. In other words, what wage will induce a man to work one more hour? This involves a choice of one more hour of working versus one hour of leisure. In agriculture, the choice is a free one; a man can loaf most of the time or work all the time, depending on his ambition. In industry the choice is more restricted. He can work eight hours a day or not work. Occasionally he may have the opportunity to work overtime.

It is believed that a yearly wage determines whether a man will farm or not. If an opportunity exists in an alternative occupation of earning \$2500 per year at eight hours per day, the farmer will have to earn some comparable wage at comparable hours to afford to stay on the farm. Let it be assumed that \$2000 per year at an average of nine hours per day will be sufficient incentive to keep the farmer on the farm. The number of acres of a given kind of land that will produce \$2000 and still keep within the average of nine hours per day determines the minimum size of farm. If it is impossible to farm enough acres with short enough hours per day and high enough wages per year to compare with the highest alternative occupation, the farmer will not farm.

If for the moment it is assumed that the farmer can earn \$50.00 per acre with nine hours or less effort per day, then the absolute minimum size of farm for this man would be forty acres.

The determinants of the maximum size of farm can be shown on Figure 19.

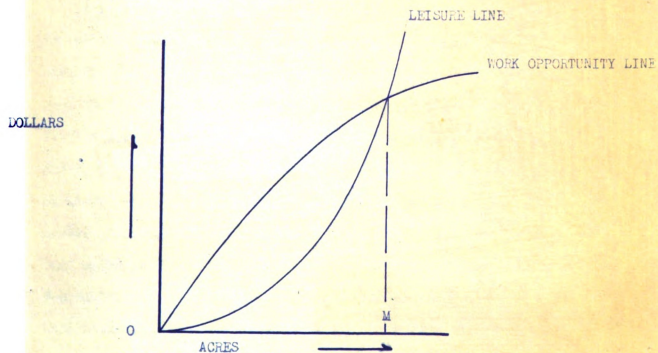
As additional acres are worked by one man, after a point the law of diminishing physical productivity sets in so that each additional acre earns less than the previous one. At the same time, the leisure given up by working the additional acre becomes more and more valuable as each additional acre is worked. Finally a point Y is reached where the value of working the additional acre is equal to the value of the leisure time lost. This is the maximum size of farm under the given conditions existing on the farm. For every farmer the minimum and maximum size of farm will be different. In general it is thought that since wage opportunities in alternative occupations are generally on the same wage level for unskilled or semi-skilled people of the farm class and that ambition is probably distributed normally in the farm population, that for any given farming area, size of farm ought to be distributed much like the curve of ambition to work additional hours or to give up additional hours of leisure.

This theory explains how it is possible for good agricultural land to remain idle several miles from town. There is simply not enough opportunity wage from farming with the type of farming and the working conditions available for anyone to farm it. This applies also to poorer land much farther from town.

The logic is this: if a man with ability enough to farm successfully in the outlying areas now moves near town, his opportunity wage in industry increases faster than his opportunity wage in farming under comparable working conditions; thus he cannot afford to farm. The opportunity wage in farming near towns used to be high enough to make farming worthwhile;

FIGURE 19

DETERMINANTS OF THE MAXIMUM SIZE OF FARM FOR ONE INDIVIDUAL



however, conditions in town are now such that the opportunity wages are relatively higher than those in farming. This explains also why formerly good farmers are now living on their farms and driving to town to work. At the same time, these men cannot find anyone to work their fully equipped farms. If they find a man with ability enough to farm, he, like his boss, can make more money working in town. If the farmer hires a man of low ability and low opportunity wage in town, he probably will not succeed in farming for the same reasons he does not succeed elsewhere.

This theory also indicates why people of low natural ability migrate to poorer farming regions. Suppose there are two men, one of whom has high ability with an alternative wage of \$3000 per year, the other of whom is lower in ability and has an alternative wage of \$1500 per year. Further assume there are two land types, one earning \$30 per acre, the other, \$15. Both men are willing to work ten hours per day. If the farmer of higher ability works the good land, he will have to work 100 acres. This he can do in ten hours or less per day. But to work the poor land would require a 200 acre farm, one too large for one man to farm. The man with lesser ability could farm the good land and have only a 50 acre farm to earn his alternative wage. He could also farm 100 acres of the poorer land, something the more capable farmer could not afford to do.

If the assumption that the good land earns \$30 per acre and the poor land earns \$15 is put in more realistic terms, it seems likely that on either grade of land the good farmer could earn more money per acre than the poor farmer. Thus he can afford to pay a higher rent or price per acre than the less fortunately endowed farmer. Thus he tends to acquire

more of the good land than the poor farmer for two reasons. The good man will not bid on the poor land and he can afford to pay a higher price for the good land than his competitors. This does not eliminate people of low ability from good farming areas, but it does tend to eliminate the better class farmers from poor land. It should be stated that if a good farmer does farm poor land, it is apt to be larger acreages than on better land with more labor and machinery. This explains the very large farms run by excellent farmers on poor land.

If the land is poor enough, even the poor farmer cannot afford to farm there. In such cases the land is not farmed and may remain as idle farmland or go into some other use as forestry or wildlife reserves.

In the preceding analysis, each individual had different indifference curves and different wage opportunities than every other individual. The same is true for any single person over a given period of time. Since the size of farm selected by any one individual to farm is chosen only once or twice in his lifetime, this question deserves some attention.

The minimum size of farm is determined in the preceding analysis by dividing the alternative wage by the net earnings per acre. If then the working conditions on the farm are comparable with alternative working conditions and the marginal disutility of labor is low enough to allow production at all, the farm will be farmed. There are two essential factors to be studied in finding if different sizes of farms will be selected by the same person at different ages. The first factor is the net earnings per acre available to the individual. Figures from the Metropolitan Life Insurance Company (24) show that farmers incomes do increase with age up to about age fifty. Part of this effect is due to

added acres and part to added income per acre. The other factor to consider is the alternative wage per year available at different ages to the same individual. If a man is farming, his alternative wage will increase in an alternative occupation only as his productivity increases. Very probably not only as his productivity increases but as productivity for men of his age increases. Productivity per man in such skills as factory work increases until about age thirty-five and then decreases.

An example of the minimum size of farm that a person at different ages would select is shown in Figure 20.

If the alternative wage is divided by the net returns per acre at any age, the minimum size of farm can be found that that person would select. The size of farm that any individual would select would be different from all other individuals. It is felt that there is probably enough similarity between individuals as to alternative wage and physical productivity that some general curves could be drawn to show the minimum size of farm that persons at different ages would buy or rent.

The maximum size of farm would also change with the age of the individual entering farming. In addition to (net income) productivity per acre increasing with age as given above, probably there is a decrease in the marginal utility of leisure from age twenty-five to perhaps age fifty. After that added leisure becomes more desirable. These relationships are shown in Figure 21. In this table the maximum number of acres that a man would work increases to age fifty and then decreases sharply.

General Discussion of Factors Affecting Intensity

In the previous section, average profit per acre was assumed to be due to some type of farming prevailing in an area. In this section the

FIGURE 20

MINIMUM FARM SIZE SELECTION BY AGE FOR ONE INDIVIDUAL

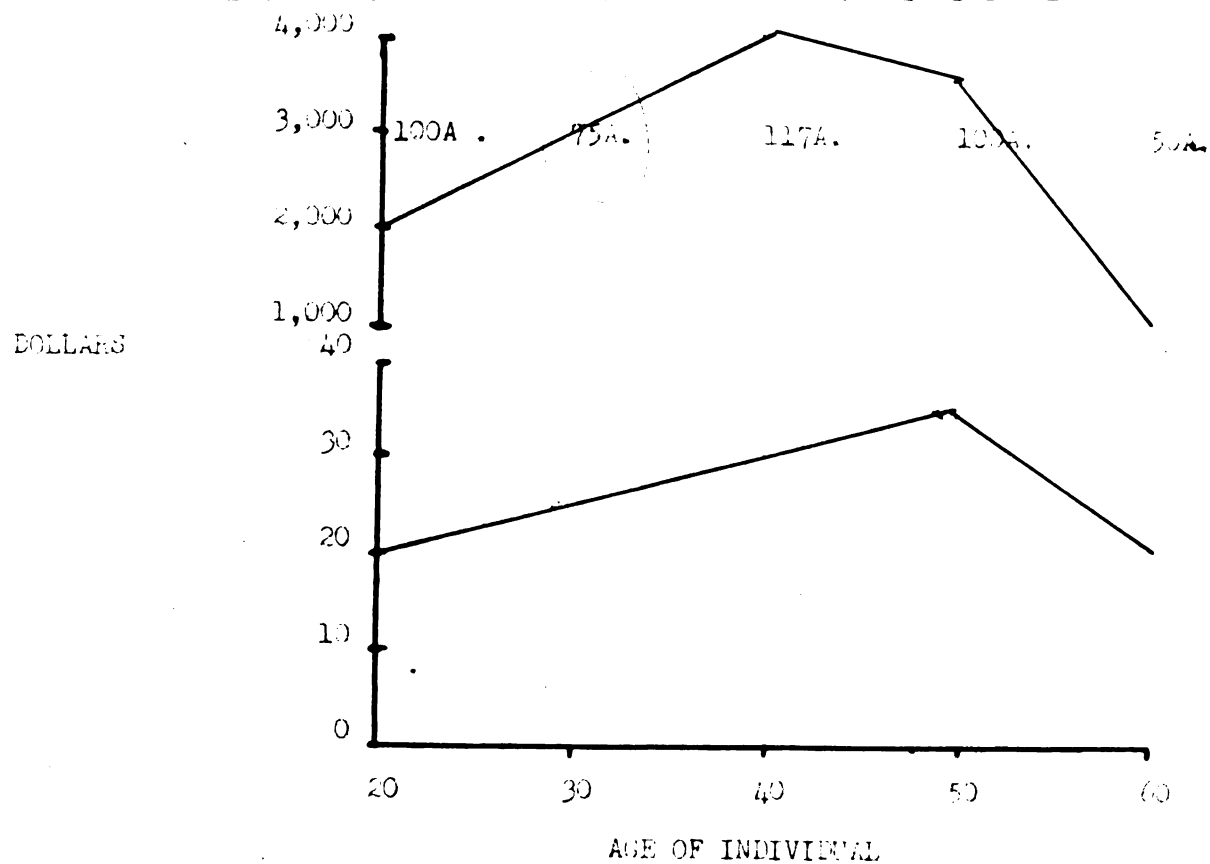
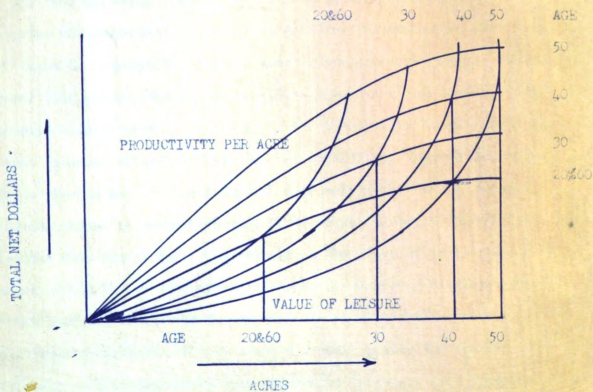


FIGURE 21

MAXIMUM SIZE OF FARM SELECTED BY ONE INDIVIDUAL AT VARIOUS AGES



factors dealing with the farming types, that is, differences in farming due to differences in intensity of production will be discussed.

To understand the changes in intensity from place to place and from farm to farm requires the knowledge of the nature of production, and particularly agricultural production. The principles of diminishing marginal substitution and of diminishing marginal productivity prevent all the food and other products of farms from being grown adjacent to the areas of consumption. Von Thunen and Weber in particular have shown that there is a system to land and natural resource utilization. In general this system consists of producing products in one location and consuming them in another. Frequently the consumption location will be several thousand miles from the place of production. Weber (43) showed that in the process of production and consumption that weight moved in production added to production cost while weight moved in consumption detracted from the price of the product at the place of production. Because of the law of diminishing physical productivity the total production that can be secured in any one area is ultimately limited. In the attempt to produce all that consumers want, production spreads out over space so that production cost constantly increases as a function of the cost per mile away from the market for production goods and that price received for the product decreases as distance from market diminishes.

Each enterprise in production thus is forced to compete with every other enterprise so that each will be located at the point of greatest net economic advantage, that is, where the economic rent for any one enterprise is greater than for any competing enterprise.

If it were possible all production should take place in the same place as all consumption so that there would be no transportation costs. To put it another way: if there were no costs of transportation, production could take place wherever it suited the fancy of the people.

Economists for years have shown that there are definite patterns of production. Von Thunen in 1826 showed this as a series of rings around the central marketplace laying on a broad homogeneous plain. By deductive analysis he showed that there are areas of greatest net economic advantage for each enterprise and that these are determined by costs of transportation. Alfred Weber improved on Von Thunen's notion by including more variables in his analysis. He worked out mathematically a system showing that points of net economic advantage of production depend on the weight loss in processing a material for consumption. Aereboe and Brinkman worked more specifically with agriculture and advanced theories of broad land use based on the theories of their predecessors.

In the United States, Gray (13), Taylor (33) and others at Wisconsin did considerable work in the broad theory of land economics. Other economists contributed along the way; Black (4), Bunce (7), Hoover (19), Hammar (14) and others made their contributions.

Even with all this work, there remains practically no literature that deals specifically with causes for land use in local areas. In the pages following, an attempt is made to bring the contributions of past workers into a logical scheme to show why natural environment affects social and economic structure within a region.

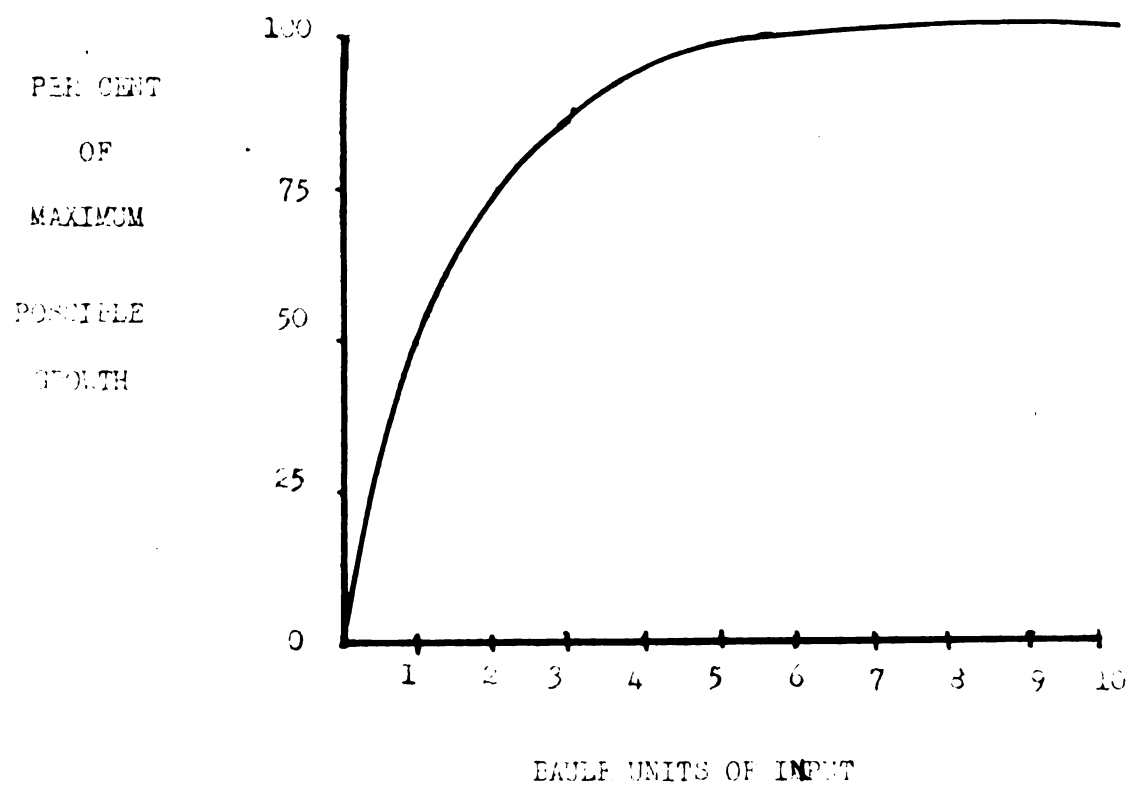
The first idea of importance in the study of land use intensity has probably been known for centuries. The idea is attributed to

Mitscherlich (27) in Germany. This idea is the law of diminishing physical productivity. Baule (3) and Willcox (44) expanded on the law and gave it the graphic form of Figure 22, Baule was responsible for transposing the verbal principle into mathematical terms. Baule developed the so called "Baule unit" so that any attribute of plant growth that affected yield could be expressed mathematically in terms of physical efficiency. Baule derived from the experimental work of Mitscherlich the mathematical law of plant growth and found that if any element of growth such as nitrogen were studied, it was possible to find in a soil a minimum amount of the element that would produce the maximum amount of growth. Once the minimum amount necessary to produce the maximum growth were found, it was possible to divide the amount of growth factor into ten equal parts and assign a percentage of growth term to each of the ten units of the factor. For example, Baule found that following the asymptotic growth curve that the first of the ten units of the growth factor (Baule units) would produce 50 per cent of the maximum growth possible for any plant with the element nitrogen. The second Baule unit would produce an additional 25 per cent of the maximum growth possible, or 75 per cent of the maximum growth. The third unit would add 12.5 per cent for a total of 87.5 per cent of maximum growth and so on.

Maximum growth for any plant could be experimentally determined. Mitscherlich found that the nitrogen content of a plant determined the maximum growth possible and that if a constant which had been experimentally determined for all plants were divided by the nitrogen content of a given plant that the maximum yield per acre could be determined.

FIGURE 11

THE LAW OF DIMINISHING PHYSICAL PRODUCTIVITY (AFTER BAILEY)



This mathematical expression of physical efficiency made it possible to estimate yields of any plant if the nitrogen content of the plant and the Baule units of plant growth factors were known.

The method for determining physical efficiency is the per cent of yield produced by each growth producing factor such as water, stand count, nitrogen, climate or phosphorus, (Mitscherlich claimed that any of these could be characterized by Baule units.) multiplied by each other. If there were 2 Baule units of Nitrogen in the soil, 10 Baules of water and 1 Baule of potassium the per cent of maximum yield that would be produced under such conditions would be the percentage of yield from each factor multiplied by each other. In this case it would be 75 per cent times 100 per cent times 50 per cent or a total yield of 37.5 per cent of the maximum possible yield. If this were a crop of sugar beets with a maximum yield of about eighty tons per acre according to Mitscherlich then the yield on this field would be approximately 30 tons to the acre if all other growth factors were optimum.

The above example is given to show that plant growth factors act in the same way in combination as economic efficiency factors as described by Black (4). Furthermore it is experimentally possible to characterize land in terms of Baule units of plant growth factors. Since this is true, there is some point to discussing physical efficiency and capacity of land.

The work of Mitscherlich and Willcox is by no means ended. Bray (5) working at the Illinois station has recently employed a modified Baule system for predicting yields in Illinois. Although there is considerable controversy over the work of Mitscherlich and Willcox, there remains no question that the law of diminishing physical productivity acts in some way comparable to the description given by Mitscherlich.

The law of diminishing physical productivity operates in other fields than plant growth. Spillman (52) working independently of Mitscherlich discovered the law about the same time in the United States. He found that the principle operated for animal growth, machine operation, human labor application and in many other activities. Economists have shown that there is a like law operating in the substitution of one factor of production for another. This is termed the law of diminishing marginal substitution. The two laws combine in practice to give rise to the general concept of diminishing marginal returns.

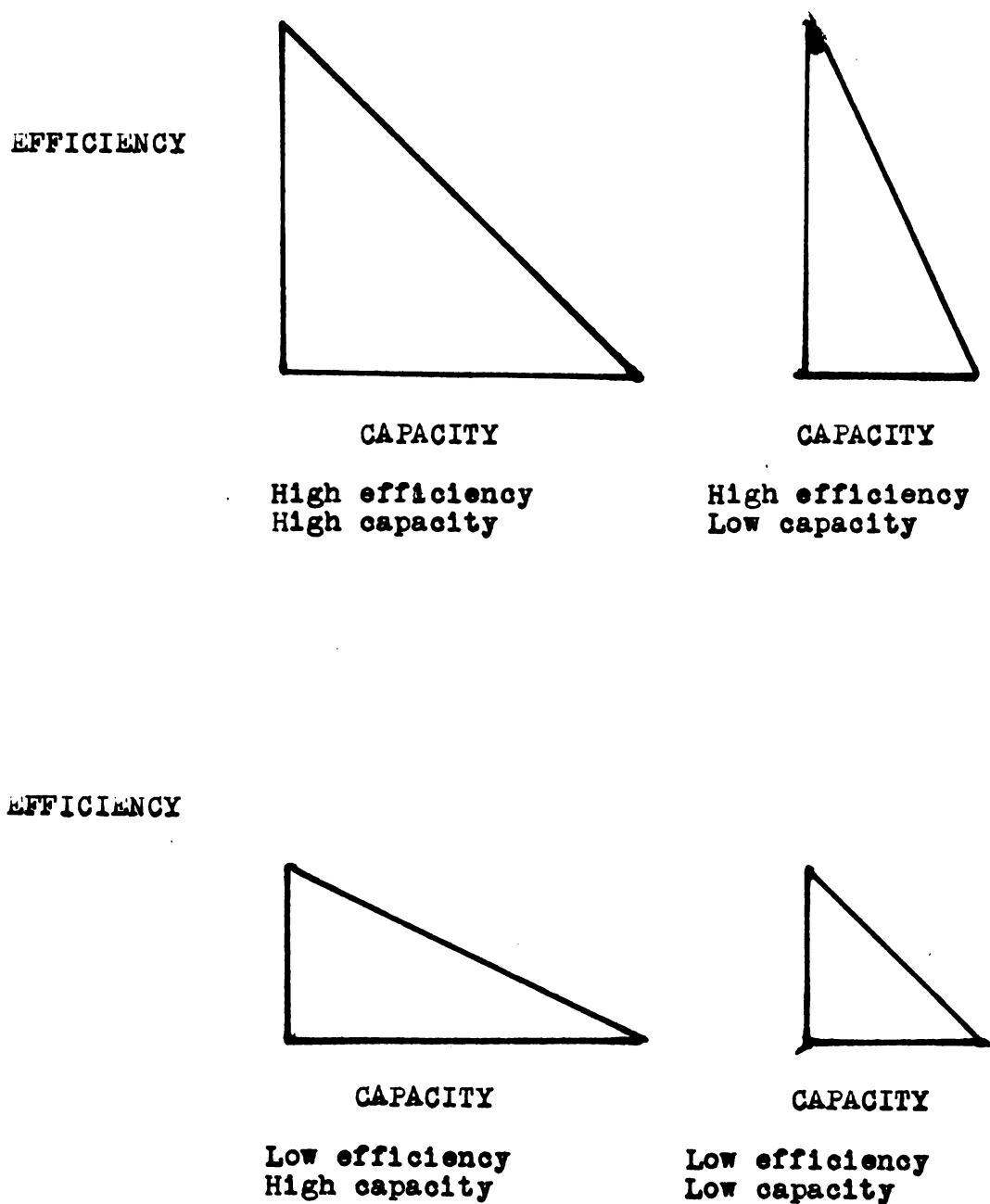
In regard to characterizing land as a factor of production, Black (4) and Hammar (15) at least have applied the law of diminishing physical productivity to land and have concluded that insofar as physical capacity and efficiency are concerned, that there exists four kinds of land. The four kinds are land with high capacity, low efficiency; land with high capacity, high efficiency; land with low capacity, low efficiency and land with low capacity and high efficiency.

These four types of land are shown in Figure 23. The construction of the figure should be explained. Capacity is measured horizontally. It is the total physical ability of land to return a yield for inputs to land of capital and labor. The table is based on the known fact that some soils have greater ability than others to absorb inputs. Efficiency as a general term is the ratio of outputs per input. Marginal efficiency is measured vertically in the figure, it is the marginal output per marginal input. If inputs are considered as completely divisible, a line drawn vertically from the horizontal axis at any input gives the marginal output for that unit of input. Total yield can be determined by adding

FIGURE 23

OUTPUT OR USE ELASTICITY CURVES

FOR FOUR THEORETICAL TYPES OF LAND (AFTER BLACK AND HAMMAR)



the marginal increments of outputs to the left on the diagram plus the increment of the input in question. The curves in Figure 23 are derived from the work of Mitscherlich mentioned before. A term that can be applied to such curves is use elasticity curve or input elasticity curve; the rate of change of marginal output in response to a small change in input.

For every piece of natural land, every soil type or every soil type phase, there are literally dozens of physical use elasticity curves. There is a different curve for each use on each land type and a different curve for every association of uses on a given natural land type. Thus a soil might have high efficiency--high capacity for beans in one farming system but low efficiency--high capacity for the same crop under a different rotation system. Generally, however, soil types are considered to retain their capacity-efficiency relationships over a considerable range of land use. Thus muck soils are considered to have high capacity--high efficiency for a considerable variety of vegetable crops. These same soils have low efficiency--high capacity for **timber** crops.

Economics cannot change the capacity of land. This is because capacity is a physical concept. It may never pay to expand production to the physical capacity, nevertheless, the opportunity for physical expansion exists. Black (4) has a different concept of economic capacity. He claims that economic capacity is the sum of all marginal positive economic efficiencies, that is the highest profit combination. If Black is correct, and if his is the right concept, it is not a very useful concept, because, for every change in price of either input or output, a different capacity of land results. Since capacity is generally a measure

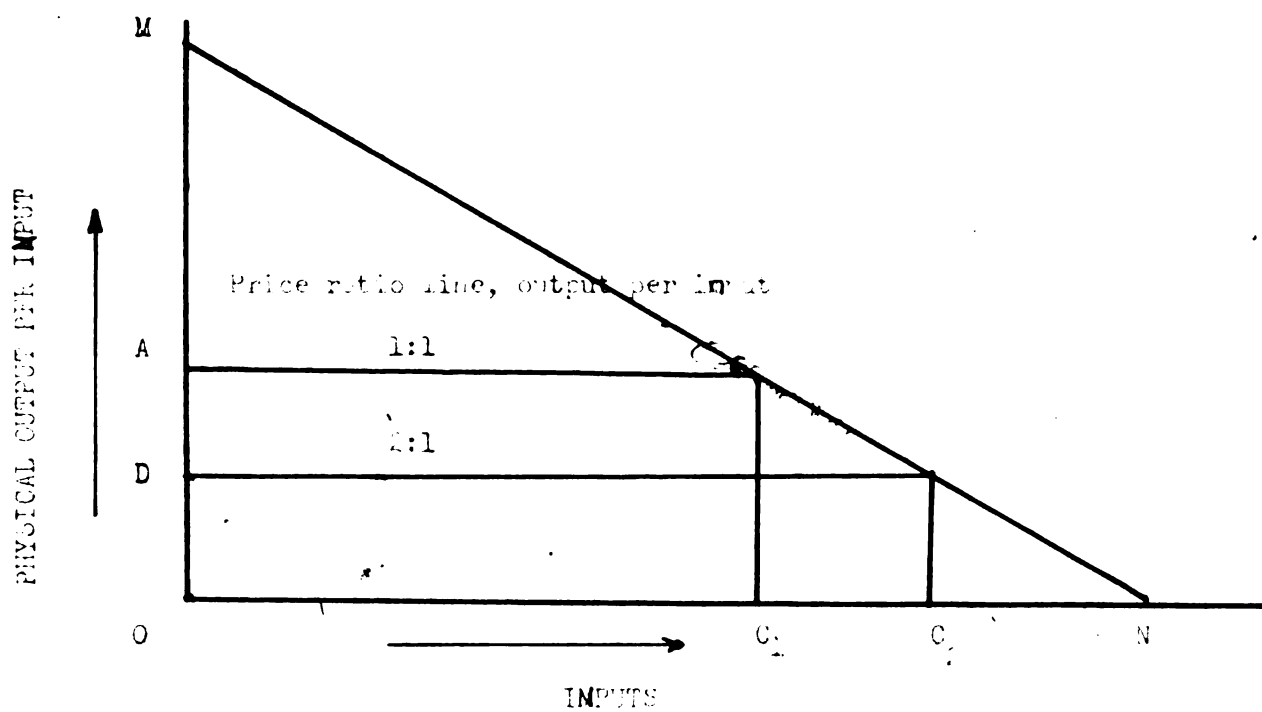
of size, it might be more useful to think of capacity as the ultimate physical yield possible. Then, for any ratio of output-input prices, at any positive marginal physical output, there will be some positive rate of return on input. This positive rate may be ten cents return on ten dollars input, it is a positive rate of return, nevertheless. Only when the marginal physical output is zero or when one of the prices of either output or input is zero will the rate of return on input be zero and the physical and economic efficiencies differ. In the former case when the marginal physical yield is zero, the physical capacity is reached. In the latter case with one of the prices of either input or output is zero a non-economic situation is the result. Thus physical and economic capacity are always measured at the same point.

Economic efficiency, on the other hand, is a different concept than physical efficiency. It is measured by economic output per economic input. Marginal economic efficiency is calculated by multiplying the marginal physical output by the price of output. The figure obtained is divided by the marginal physical input times the price of input.

For example, to show the concepts of capacity and efficiency that have been discussed, suppose that land type A has a certain input elasticity curve for growing potatoes (MP). If the ratio of prices is 1 bushel of output equal in value to one unit of input, then a price line AB_1 can be drawn on Figure 24 to indicate the point B_1 where the value of the marginal output B_1C_1 is equal to the value of the marginal input C_1 , that is, the highest profit combination under free competition. Thus, by marginal analysis using the physical use elasticity curve and the ratio of prices of output to input, it can be seen that CC_1 inputs will be used

FIGURE 24

USE ELASTICITY CURVE FOR POTATOES ON NATURAL LAND TYPE A.



and that the total yield of potatoes on land type A will be the area OMB_1C_1 at the highest profit combination.

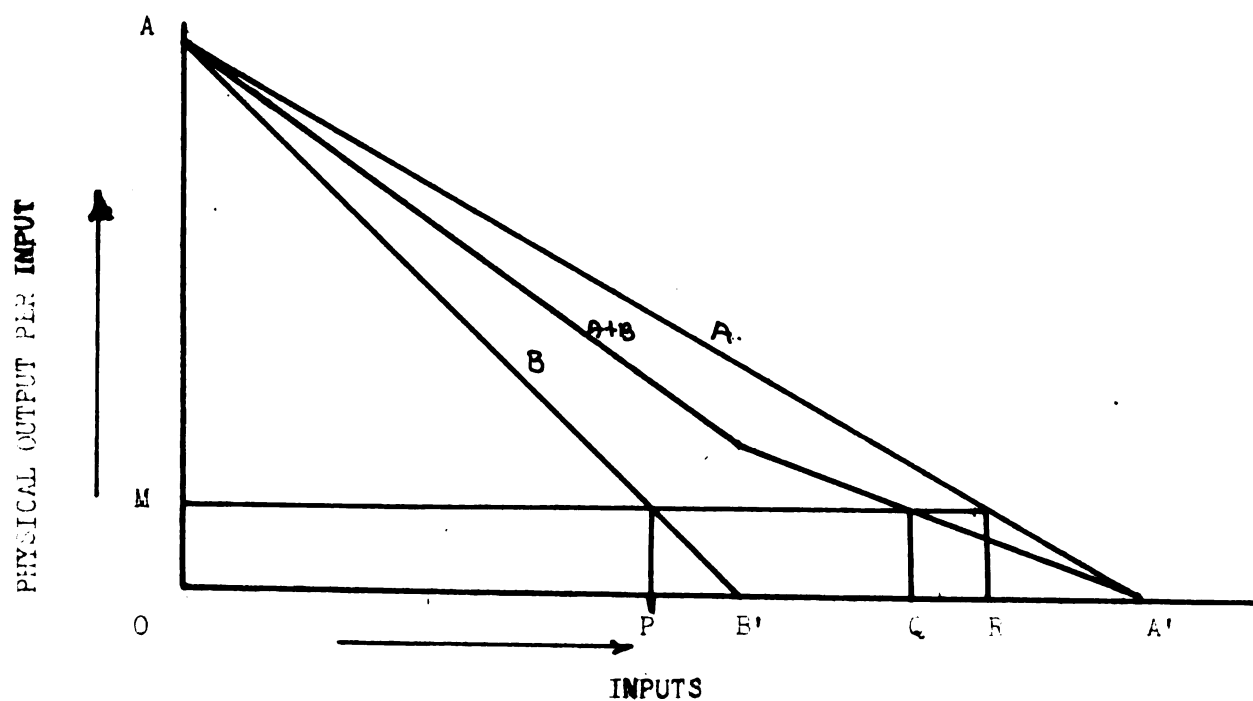
The usefulness of plotting ratios of prices on a physical marginal productivity curve is immediately evident. If, instead of a ratio of prices of output to input of 1:1, there is a ratio of 2:1, the new price line will be DB_2 and input use will increase to OC_2 and total production to the area OMB_2C_2 .

Since curves for land such as given in Figure 24 do exist for land types and soil types, it would be well to investigate some theoretical aspects of use and particularly of soil and land productivity.

Suppose that there exists in a region in a virgin condition, three land types. The first is composed of soil type A with use elasticity curve AA' in Figure 25. In the same region there exists soil type B with curve AB' on the figure. In the same region there is a land complex composed of 50% of soil A and 50% of B in such a complex mixture that the soil types cannot be separated for use by the farmer. This complex can be termed A/B and its use elasticity curve will be AC' or the average of AB' plus AA' .

If the ratio of price of output to input were the line ON , the amount of input used on land type B would be OP , on land type A/B , OQ and on land type A, OR . If production were to continue for perhaps fifty years on virgin land it is unlikely that the component A of land type A will remain the same as A of land type A/B , even though in the original state they were identical components. This is due to the fact that component A of land type A receives more inputs every year per acre than A of land type A/B .

FIGURE 25
 USE ELASTICITY CURVES FOR POTATOES
 FOR EACH OF THREE NATURAL LAKE TYPES IN A REGION



This analysis of the components of land types according to the manner in which land use takes place provides a logical method for conducting soil productivity studies. It can be stated rather definitely that land used such as A/B in the example given, for several decades is not the sum of the weighted averages of land type A and land type B. It is as illogical to believe that economics plays no part in soil productivity studies as it is to believe that soil type or land type plays no part.

The conclusion that follows from this is: soil productivity studies must be based on the units of land that farmers actually use in applying inputs if research in this field is going to be realistic.

The next important step to consider the land has been characterized is to review the work of Von Thunen and Weber (41) (43) in regard to land use intensity. Von Thunen worked out in his "Isolated State" the nature of the geographic incidence of land uses around a central market city. Weber has pointed out that Von Thunen was essentially correct in his analysis of the distribution of agricultural production except he forgot one factor. This factor was the cost of transportation of inputs to the farm. Von Thunen had considered only the marketing cost of transportation in his analysis. Weber barely mentioned this omission of Von Thunen's; he did not elaborate.

If the same assumptions are employed that Von Thunen used, that of a city in the center of a homogeneous plain, it may be possible to add something to Von Thunen's work.

Perhaps it would be well to start with one product such as fluid milk, assume a market demand schedule and consider how intensity of production would vary with some factors affecting intensity. Later the

limitation of one product will be eliminated to include many products.

First, it will be necessary to characterize the land for milk production. This means that a use elasticity curve for fluid milk production at the highest profit combination on the land used will have to be assumed.

There are a number of variables to consider in this problem of varying intensity besides the use elasticity curve of land. These are: the prices of input and output, transportation cost to and from the farm and the demand schedule for milk in the market place. Other variables will be added later in the analysis.

The effect of these variables can be shown graphically. Figure 26 shows the effect of price of input and output on intensity of land use. If a use elasticity curve is given and price ratio lines are drawn on the graph, the relationship can be seen clearly.

A given relationship of output to input exists physically as is shown on the curve. At a low price of output per input, production will be at OA inputs with an output equal to the area ORSA. With a higher price, inputs will increase to OB and output from the area ORSA to ORTB, an increase of ASTB. Finally with a very high price for output in relation to input, OC inputs will be used, causing an increase in production of output of the area TBUC or a total area of ORUC.

With any curve where diminishing physical productivity is the rule, there is a point of maximum physical returns, OD, where regardless of the ratio of prices of outputs to inputs, no further production can take place even though inputs can increase.

FIGURE 26

THE EFFECT OF THE RATIO OF OUTPUT TO INPUT PRICE
ON THE INTENSITY OF LAND USE

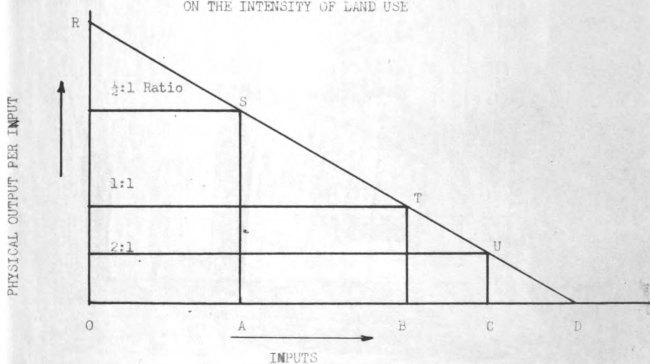


FIGURE 2

THE EFFECT OF A CHANGE IN INPUT PRICES (THEY ARE NOT
OF THE INTENSITY OF LAND USE WITH ILLEGAL FISHING
(THE INDEPENDENT VARIABLE))

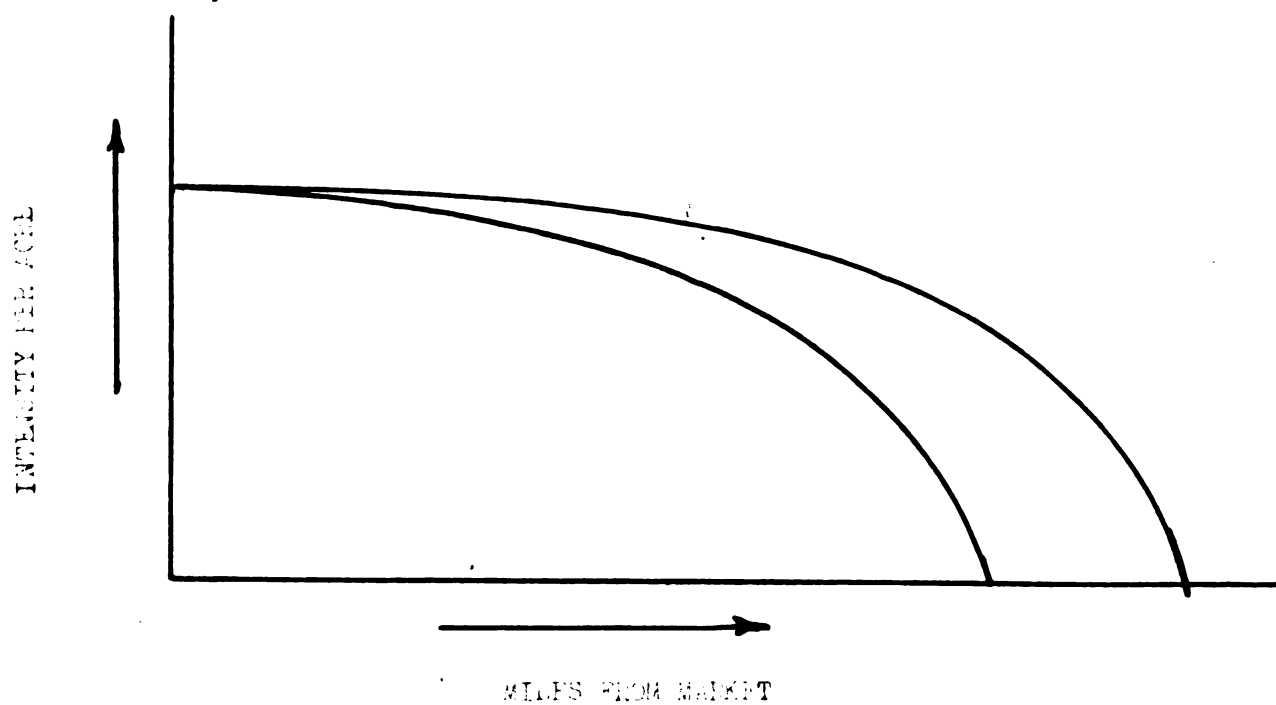


Figure 28 shows that where input involves buying and hauling equipment from market such as feed, fertilizer and machinery and even food for the family, that ultimately there would be a limit to production spatially, even if it cost nothing to carry the produce back to town to sell.

The effect will be the same as transportation cost of input, but more pronounced generally since most inputs are derived at the point of production and are not hauled to the farm; whereas all the output is hauled from the farm. In other words, even if input transportation cost were the same as output transport cost per unit of weight, the effect on the area of production would be much less from input (an increase in the cost of production) than to output transport cost (a decrease in the selling price of the product). This would be true in most cases of agricultural production, at least.

When transportation costs change, they change in the same way for both outputs and inputs. This produces an accentuated effect on the intensity of production in a given place. The changes in intensity associated with both changes in output and input transportation cost at the same time are shown in Figure 29.

These examples are not the only factors affecting intensity of production. Others such as the personal qualities of the entrepreneur, institutional factors of production, irrational behavior, ~~technological~~ ^{technological} changes and other factors could be included. Enough of the important factors affecting intensity have been given to understand the nature of the problem.

FIGURE 28

THE EFFECT OF A CHANGE IN OUTPUT TRANSPORTATION COST
ON THE INTENSITY OF LAND USE

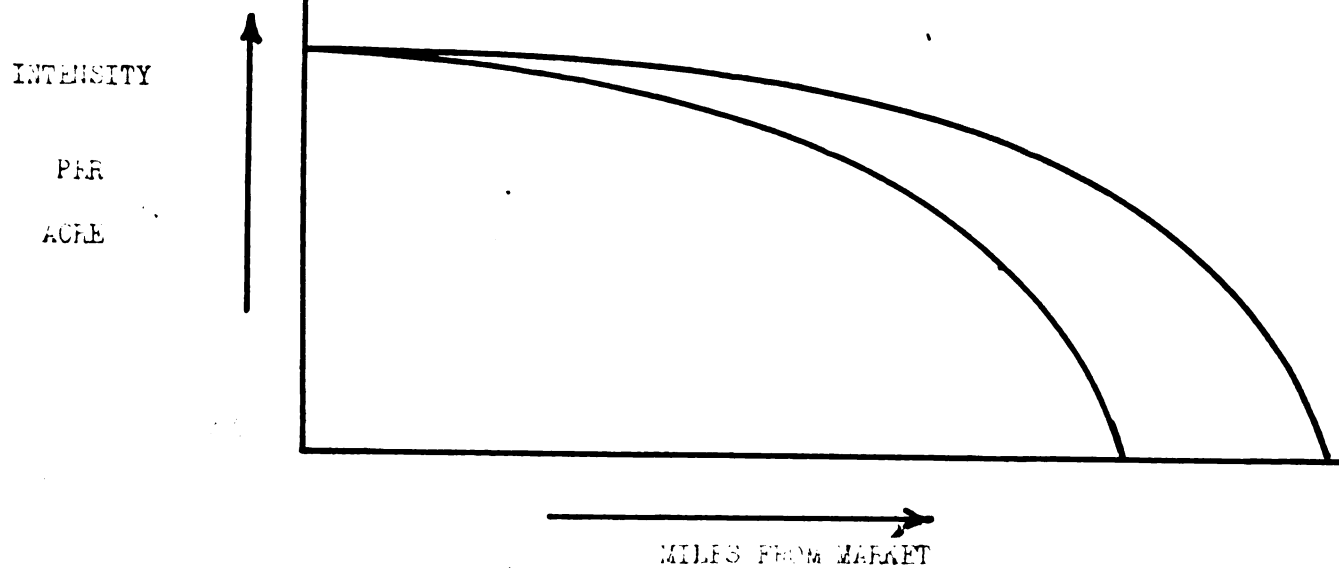
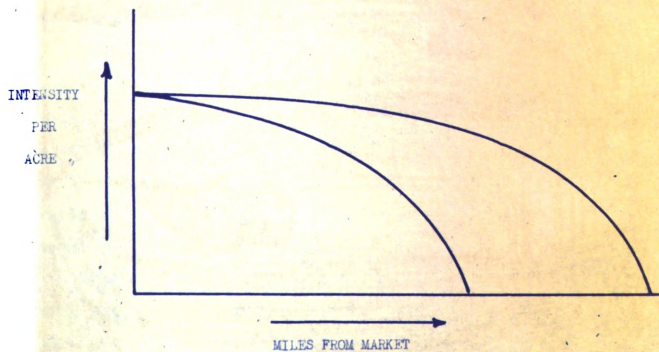


FIGURE 29

THE EFFECT OF A CHANGE IN BOTH INPUT AND OUTPUT TRANSPORTATION COST
ON THE INTENSITY OF LAND USE



The Effect of Distance from Market on Farming Systems

Essentially there are two elements in calculating where production of farm products will take place. The first lies in discovering physical characteristics of the land, its capacity and efficiency, under all production systems physically possible. Secondly the economics of production must be known. It is the interaction of physical characteristics of production with the economic characteristics that produce apparently haphazard land use patterns.

If a theoretical example is taken, the factors that determine the location of various land uses can be seen more clearly.

In discovering where production will take place, it is necessary to know the physical limitations of land for all possible agricultural products. Let it be assumed that there is a city lying in the center of a homogeneous plain and that the land of the plain has the characteristics for production of its three possible products, sugar beets, dry beans and barley as given in Table XXII at the various levels of a variable input, in this case fertilizer.

It should be pointed out that if the land had either different possible uses or different use elasticity elasticities than given in Table XXII, that this would affect the whole land use picture in this problem.

After all characteristics of physical use are known, the answer to the problem of location of agricultural production lies in economic considerations. All the economic facts that need to be known are given in Tables XXIII, XXIV, and XXV. The implicit assumption is made in the tables that capital cannot be substituted for labor. This is not true, of course, but can be assumed in this problem.

TABLE XXII

THE EFFECT OF APPLICATION OF A VARIABLE INPUT (FERTILIZER)
ON THE YIELD OF SUGAR BEETS, DRY BEANS AND BARLEY ON A
HYPOTHETICAL NATURAL LAND TYPE

Amount of fertilizer pounds	Yield		
	Sugar Beets pounds	Dry Beans pounds	Barley pounds
0	10,000	1,000	800
100	12,000	1,300	1,300
200	13,800	1,500	1,750
300	15,300	1,600	2,150
400	16,500	1,650	2,450
500	17,400	1,650	2,650
600	18,000		2,750
700	18,300		2,800
800	18,500		2,800
900	18,600		
1000	18,600		

TABLE XMIII

FACTOR COSTS AT THE FARM AT VARIOUS DISTANCES FROM THE CITY

Miles	Cost of fertilizer per 100 pounds	Cost per hour or labor	Cost of Machinery
0	3.00	1.00	1.00
10	3.10	.83	1.05
20	3.20	.67	1.10
30	3.30	.50	1.15
40	3.40	.50	1.20
50	3.50	.50	1.25
60	3.60	.50	1.30
70	3.70	.50	1.35
80	3.80	.50	1.40
90	3.90	.50	1.45
100	4.00	.50	1.50

TABLE XXIV

COSTS OF PRODUCTION IN DOLLARS AT ZERO DISTANCE FROM THE CITY

Crop	Fertilizer	Labor	Machinery
Sugar Beets	21.00	60.00	40.00
Dry Beans	12.00	20.00	20.00
Barley	18.00	10.00	20.00

TABLE XXV

COMMODITY PRICES AT THE FARM AT VARIOUS DISTANCES FROM THE CITY
FOR SUGAR BEETS, BEANS AND BARLEY

Distance in miles	Crop		
	Sugar beets Cents per lb.	Dry beans Cents per lb.	Barley Cents per lb.
0	1.2	6.0	4.0
10	1.1	5.9	3.9
20	1.0	5.8	3.8
30	0.9	5.7	3.7
40	0.8	5.6	3.6
50	0.7	5.5	3.5
60	0.6	5.4	3.4
70	0.5	5.3	3.3
80	0.4	5.2	3.2
90	0.3	5.1	3.1
100	0.2	5.0	3.0

The price of labor was assumed to vary as the cost of transporting a worker to town every day of the year out to a point where the wages per hour became so low as to cause a worker to move into town rather than to drive to town each day. The point at which a worker would move to town was assumed to be the floor for agricultural wages for the manager-worker combination found on a one-man farm. The cost of capital goods was assumed to increase for at least two reasons. There is a transport cost in moving production goods such as tractors and tile. Secondly the interest charges on capital itself would increase with distance due to an increasing scarcity of capital for production purposes. Lastly, the price of fertilizer increased in price according to a set transportation cost and product prices decreased for the same reason.

With the information at hand, the location of production can be discovered. The yield of a crop on a given soil is the function of the amount of variable inputs such as fertilizer, increased tillage or more intensive spraying, if all their conditions for growth are optimum. In this problem the only variable input included is fertilizer. Von Thunen listed two costs in the production of rye, that dependent on the price of rye and that independent of the price of rye. In more modern terms these would be variable costs and fixed costs. An economic principle which states that production will be pushed to the point where the marginal unit of the last variable input is equal to the value of the marginal increase in yield from the variable input, is the determinant of the level of production that will be used on any given soil.

As an example, if barley sells for four cents per pound and fertilizer costs \$3.00 per input, that is 100 pounds, it will take 75 pounds

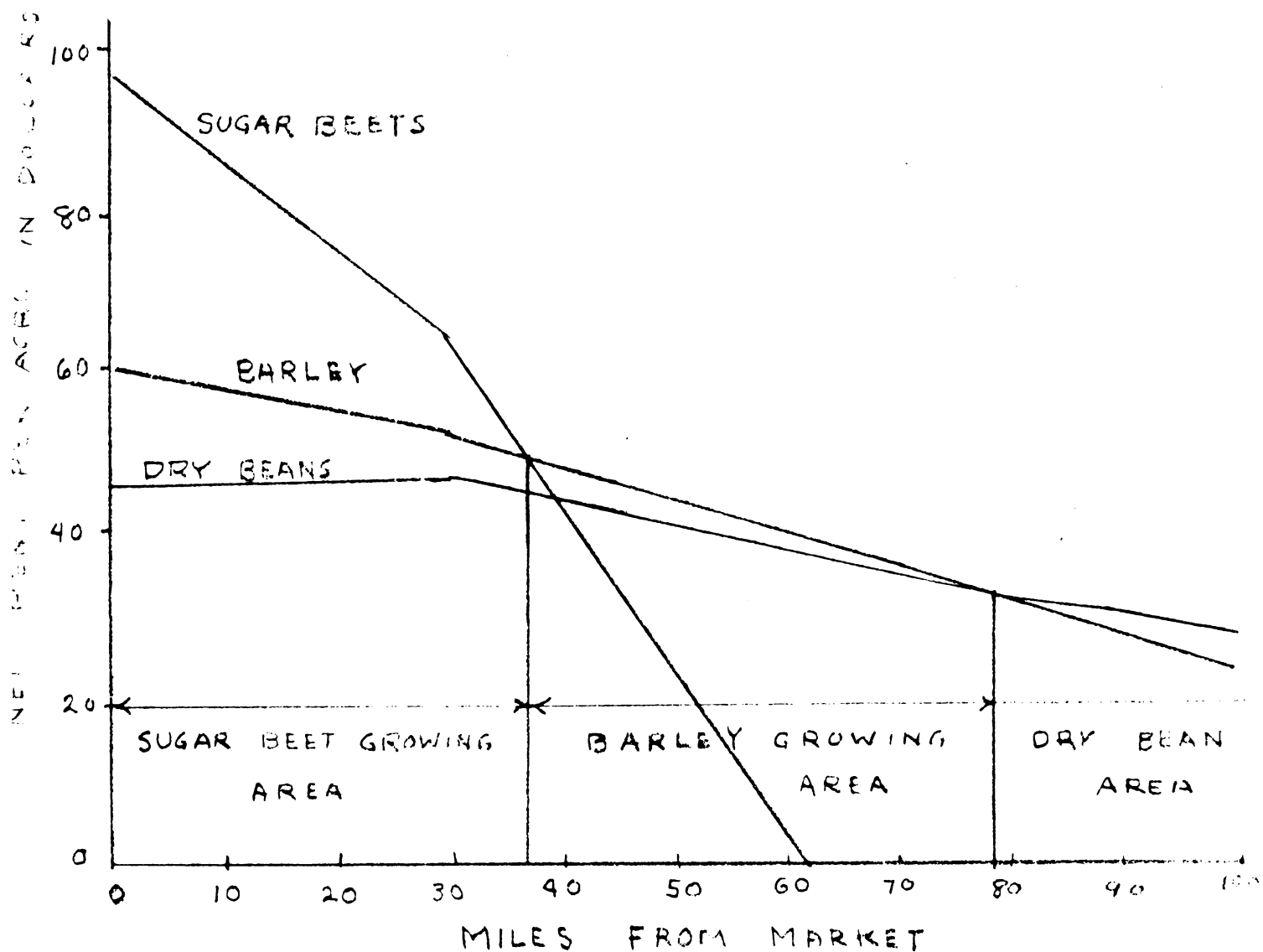
of barley to pay for the fertilizer. In the example given, the sixth bag of fertilizer increases yield by 100 pounds and the seventh by 50 lbs. The sixth unit would be used rather than the seventh and if sacks of fertilizer could be split up, a little over 600 pounds of fertilizer would be used. Thus 2750 pounds of barley would be produced per acre.

It is the variable input that determines the optimum point of production. The fixed inputs when added to the variables determine whether a farmer should attempt production or not. If when the variable costs and fixed costs are added together and the sum is less than or equal to the total revenue from selling the product, production should be attempted if the use in mind is the highest economic use.

To recapitulate, there exist in the central market, prices for factors of farm production and prices for farm products, which are determined by forces of supply and demand. There is a price for transporting goods. All these factors interact with the physical characteristics of the prevailing land type to give rise to an economic rent at any point selected. Figure 30 gives all the economic rents possible for sugar beet, dry bean, and barley production for all points from zero to 100 miles from the central market. In the example chosen, all crops could be economically grown at all points included on the chart. However, the one that would be grown is determined by the law of comparative advantage. This principle says that the use producing the greatest economic rent per acre will capture use of the land. In the example given sugar beets would occupy distance OA. Point A would be the margin of transference to barley. Barley will have the use of land from A to B and from B beans will occupy the land to some next margin of transference.

FIGURE 30

MARGINS OF TRANSFERENCE FOR THREE CROPS
WITH DISTANCE FROM MARKET IN A HYPOTHETICAL SITUATION



Factors Affecting Enterprises that Will be Conducted on a Farm

The analysis of the best combination of inputs to result in the highest profit can be found in any textbook of Production Economics. The purpose here is not to solve this problem but rather to indicate how certain enterprises tend to be used by a farmer.

The size of farm and habits of farming were originally determined in any area by a combination of factors. Among these were the opportunity for selling farm products, the price at which they could be sold, the products that could be produced and their costs of production and finally, the physical and mental capacity of the farmer and his alternative wage.

It can be assumed here then that the size of farm has been determined by historical events. If the size of farm is taken as given for any particular short-time production period and it is assumed that one man is available for labor and management, the factors which determine what enterprises will be undertaken can be studied.

With the amount of land and labor given, the problem of the best combination of inputs and what inputs to combine can be found by discovering the combination that gives the greatest net profit per acre. This combination can only be found by analyzing all available combinations of enterprises.

As an example, suppose the opportunities for growing only wheat, oats or red clover seed as cash crops exist on a farm. What are the factors that determine which of these crops will be grown and in what proportions? It is known that crop yields vary with crop rotation or crop sequence on any individual natural land type. All possible sequences of crops are given in Table XIX for the three crops: wheat, oats and red ~~clover~~.

TABLE XIX

ALL POSSIBLE CROP SEQUENCES WITH EXPECTED YIELDS ON A
HYPOTHETICAL FARM

Crop	Yield						
Wheat alone	12						
Oats alone	15						
Clover seed alone	100						
Wheat	15	plus	Oats	20			
Wheat	25	plus	Clover	200			
Oats	35	plus	Clover	200			
Wheat	20	plus	Oats	25	plus	Clover	150
Oats	30	plus	Wheat	18	plus	Clover	150

With the yields given in Table XIX, if costs of production were as follows: Oats--\$20.00 per A., Wheat--\$20.00 per A. and Clover seed--\$20.00 per A., if grown alone and \$10 per A. if grown with a grain crop and.....Suppose wheat were \$2.00 a bushel, oats, \$1.00/bu. and red clover seed, \$.30 a pound, which combination would the farmer use?

Wheat-red clover seed with \$40 per year net profit would be the winning combination for this farm and half the farm would be devoted to wheat and half to red clover. This problem can be summarized to state that the enterprises grown on this farm depend upon the price of input, the price of output and the physical productivity of soil.

All the crop sequences are for static production conditions. If this limitation is eliminated, how will this change the crops grown? If only one example is chosen, for example the crop sequence wheat-red clover seed, how will the addition of fertilizer affect the cost combinations and how much fertilizer will the farmer employ at the highest profit combination? Table XXI gives the yields the farmer could expect for each increment of fertilizer added.

The most profitable amount of this fertilizer would have been 500 pounds per acre. If the complete analysis were done, the effect of fertilizer on all crop sequences would have to be studied and perhaps the highest profit combination would then not have been the wheat-clover sequence. Such analysis could be carried out for use of any other input such as irrigation water or additional tillage.

The final combination of enterprises then is determined by the cost of inputs, the price of output and the physical productivity of soil at each input level plus the farmer's problem in allotting his labor supply between enterprises and using his crop rotation scheme.

TABLE XXI

NET PROFIT PER ACRE EXPECTED FROM APPLICATIONS OF A VARIABLE INPUT (FERTILIZER) ON A CROP SEQUENCE OF WHEAT-RED CLOVER SEED ON A HYPOTHETICAL FARM

Inputs of Fertilizer CFTS	Yield of Wheat Bushels	Yield of Clover Seed Pounds	Total Cost per Acre Wheat and Red Clover Seed \$	Total Revenue			Total Revenue minus Total costs \$	Net Profit per acre per year %
				Per Acre				
				Wheat \$	Seed \$	Total \$		
0	25	200	30	50	60	110	80	\$40.00
1	32	250	32	64	75	139	107	53.50
2	37	290	34	74	87	161	127	68.50
3	40	320	36	80	96	176	140	70.00
4	41	340	38	82	102	184	146	73.00
5	41	350	40	82	105	187	147	73.50*
6	41	350	42	82	105	187	145	72.50

* Highest profit combination 500 pounds of fertilizer.

* Highest profit combination 500 pounds of fertilizer.

If the type of farming is changed in the above example to include livestock enterprises, the problem becomes much more complicated, because not only are there the same factors of production to think about from the production viewpoint of the land, but physical production problems of livestock and locational production problems such as hauling in feed from surrounding areas. In addition to this complementary and supplementary enterprises add to the complications.

Even in the cash crop example, the important factor of labor distribution was omitted. This factor becomes of even greater importance if livestock is added. Livestock further complicates the production picture by changing the marginal productivity curves for land as manure is added. Thus as the livestock load increases, it increases the physical productivity of land which permits a greater livestock load. This proceeds according to the law of diminishing physical productivity; as additional livestock is added, there is less and less of a yield increase.

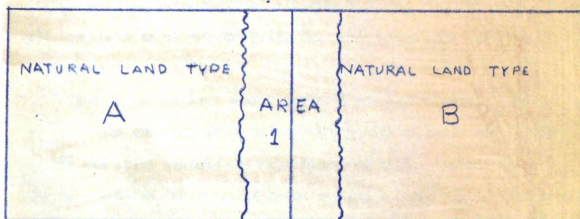
Effect of Natural Land Type Patterns on Land Use

Let us suppose there are two natural land types located adjacent to each other (Figure 31). Land type A has as its highest profit use cash grains. Hay is not adapted to this area. Land type B has as its highest use wild hay which is presently used for sheep and grass fed cattle. Under these conditions, how does the presence of land type A affect the use on land type B and vice versa?

For the purpose of analysis let it be assumed that for some reason a fluid milk market has opened in the area, so that milk is the same price and of the same shipping costs on all of areas A or B. Thus, if

FIGURE 31

FIGURE SHOWING A GEOGRAPHIC PATTERN OF TWO NATURAL LAND TYPES



A could get enough hay or B enough grain, both areas would be entirely devoted to dairy as a higher use than either cash grain or wild hay.

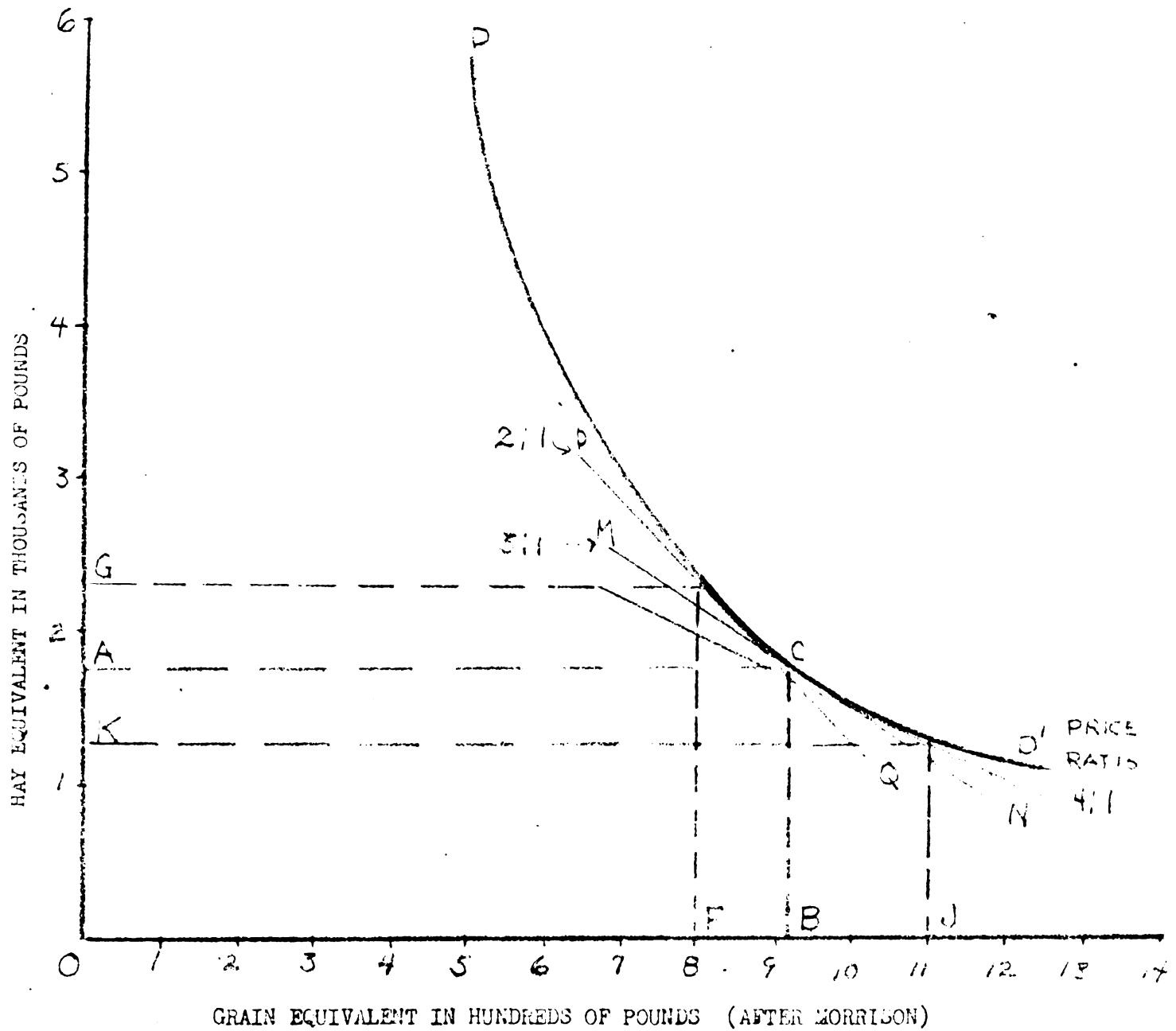
The analysis can be started in this way. There will be a small fringe of farms between A and B of perhaps half a mile to a mile in width. These farms will grow both grain and hay and thus are in the best position to raise cattle, since there is no transport cost of shipping either hay or grain.

In any problem involving the feeding of animals there are many alternative rations that can be fed to keep a cow at optimum milk flow. Figure 32 gives these alternatives with a curved line DD' which indicates all combinations of hay and grain that will maintain a cow at optimum milk production.

Thus it can be seen that a cow will eat approximately 4000 pounds of grain and 6000 pounds of hay or 1500 pounds of grain and 10,000 pounds of hay and still produce the same amount of milk. Suppose the price of hay is one-third the price of grain in area 1. The ration that will be most economical to feed will be indicated where the price line PW is tangent to DD' at C. The ration will consist of CA pounds of grain (1750 lbs.) and OB pounds of hay (9200 lbs.)

On land type A there is a shipping cost for hay but none for grain; thus less than three pounds of hay to one pound of grain should be used. Suppose this were two pounds of hay to one of grain as represented by the price line PQ. OF pounds of hay (8000 lbs.) and CG pounds of grain (2300 lbs.) should be fed as the most economical ration. Land type B has cheap hay and high-priced grain; suppose that four pounds of hay per one pound of grain is the most economical rate to feed. Then OJ pounds

SUBSTITUTABILITY CURVE OF HAY FOR GRAIN
FOR A COW PRODUCING OPTIMUM MILK SUPPLY



of hay (11,000 lbs.) and OK (1250 lbs.) would be fed. It can be seen that the use of grain or hay increases as the alternate product becomes higher in price in terms of the other commodity.

The position is now reached to answer the question of where dairying will take place.

According to Table XVI with the marginal substitutability curve of hay for grain as given and the price ratios as given, dairy production will migrate to area 1 and land type B due to the lower cost of production on these areas.

If ratios of prices should change so that land type A, changing production in B only if the price of hay became so high that the profit from hay was more than the profit from dairy cattle. In a real situation land type B could not bid up the price of grain more than a small amount because of the low price of rail transport of grain. Land type A could bid up the price of hay because of the high cost of transport, but unless the price of grain became very low and the price of hay very high, there would be very little dairying on land type A. It is conceivable under very low prices for grain that land type B would feed so much grain that there would be hay for transport to A at high prices because the comparative advantage of dairying in A would be so much better than cash grain that hay would be imported. This would happen also in periods of high hay production in B.

In a dynamic world with changing costs, there probably would be a little dairying in A close to land type B and much dairying as far into land type B as it paid to haul grain up to the margin of transference to grass fed beef.

TABLE XXVI

COMPARATIVE FEED COSTS OF MILK PRODUCTION ON TWO LAND TYPES

	Area 1	Land Type A	Land Type B
Hay	1¢/lb. \$92.00	1.5¢/lb. \$120	1¢/lb. \$110
Grain	3¢/lb. <u>52.50</u>	3¢/lb. <u>69</u>	4¢/lb. <u>50</u>
	\$144.50	\$189	\$160

It can be seen that there are many possibilities of land types affecting one another's use. Examples would include the presence of cash crop by-products, such as beet pulp or pea-vines which would draw beef cattle or other roughage-consuming livestock to the area. This could easily result in a springing up of beef breeding enterprises in the surrounding grass land natural land types. The maze of land uses that become possible under such situations becomes enormously complicated.

When the past land uses that give rise to differentiated rents become capitalized into land price, the past land uses become institutionalized into the farming system and this is probably one of the reasons that several stages in the development of land use in an area can be seen at one time.

In the real world, there are not static prices nor perfect knowledge of either prices or land. For this reason, land use probably only tends towards the most economic use. In the example given between A and B land types, dairying would probably take place in the fringe between A and B because many farmers in B would rather raise hay and sell it to B than to take the higher profits of dairying themselves. Other farmers would continue to grass feed beef in the dairy area because they didn't want to change even in the face of higher prices. Economic analysis can only show what is the tendency of use.

The Quality of Entrepreneur In Relation to Intensity of Land Use

Thus far the human element has been left out of the discussion of intensity. It was pointed out that every individual has certain desires and abilities that determine how hard he will work and to a certain extent what his yearly wage will be. In the section on the selection of

a size of farm by any particular individual, the subject was treated as if all individuals could earn the same net earnings per acre. This, of course, is not true. Where one farmer seems always to have his work done on time, the other will be two weeks late in planting his corn or harvesting his hay. These differences are difficult to define, nevertheless, they exist.

Risk of such an occurrence as crop failure may differ greatly between individuals due to the timeliness of operation, differences in quality of tillage and other factors.

The qualities of being human add complications to land use problems. The so-called institutional factors come in this category. Irrational behavior and behavior through ignorance also falls in this class. These non-rational aspects of men do not fit well into a land use theory that assumes rational actions.

It is felt that in the aggregate, however, that the irrational activities that individuals carry on will be eliminated by mass averaging. In specific areas where certain racial or ethnic groups live, these institutional factors may determine the intensity as well as the kind of land use to a great degree.

Land Use In a Region With More Than One Natural Land Type

The preceding sections have shown that land use should vary from one natural land type to another for physical and economic reasons. Perhaps it would be well to review how a seemingly meaningless pattern of land use can exist in an economic region in a perfectly logical fashion.

Suppose that there exists an economic region, a kind of an isolated state like the one pictured by Von Thunen, in which four natural land

types occur. Assume further that only four cash crops can be grown in the area and only in a continuous cropping system of one crop. These four crops are beets, barley, beans and flax. All natural land types differ in their use elasticity curves for the production of all these crops. Figure 33 indicates diagrammatically where production of each of these crops would take place on each natural land type. If now instead of a symmetrical arrangement of land type distribution, a haphazard arrangement is assumed as would actually occur in the real situation, the seemingly meaningless pattern of land use would occur as in Figure 34.

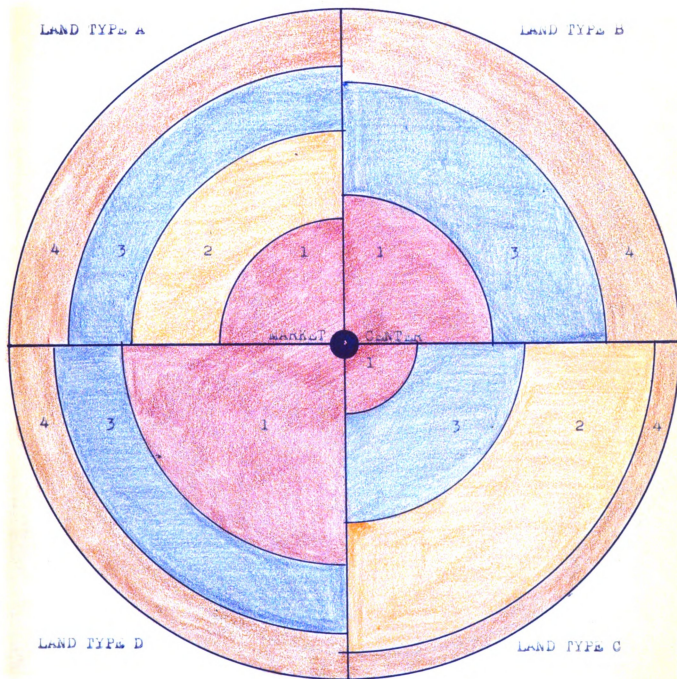
In this example, many considerations of land use have been omitted. Such effects as land type associations or patterns on land use have been omitted. There are enough of the factors of the land use problem included to indicate how the complicated patterns of land use that occur in almost any region selected could have come about.

The Dynamics of Land Use

Within one area there can be a change in one year of ten per cent or more in the amount of one crop grown. What produces these changes in crops grown and the areas in which they are grown? All the factors that determine the locations of production have been discussed before. Changing ratios of prices was shown to alter both combinations of enterprise and the location of enterprise.

One factor that was not discussed which is of great importance in determining land use is the presence of rigid costs of production. Land cost is one of the most rigid of these. If some of the so-called economic rent is capitalized into land values, all future purchasers of land become burdened with land costs of some amount. If all land were paid for in

FIGURE 33
 IDEALIZED LAND USE MAP IN A REGION
 WITH FOUR SYMMETRICALLY ARRANGED NATURAL LAND TYPES

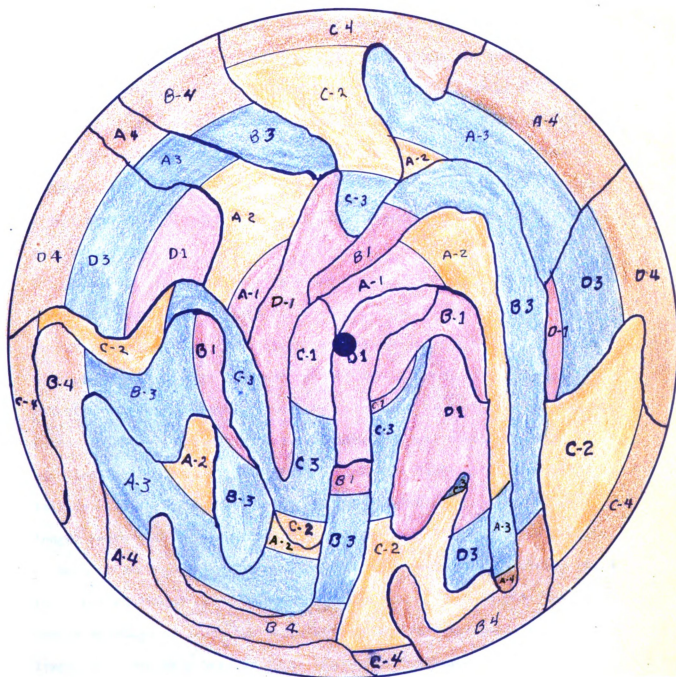


USE LEGEND

1	SUGAR BEETS
2	DRY BEANS

3	BARLEY
4	FLAX

FIGURE 34
IDENTIFIED LAND USE MAP IN A REGION
WITH FOUR NON-SYMMETRICALLY ARRANGED NATURAL LAND TYPES



USE LEGEND

1
2

SUGAR BEETS

DRY BEANS

3
4

BARLEY

FLAX

cash, this rigid cost of land would be psychological rather than real. Where fixed costs do exist in terms of debts, a price structure for production develops so that in times of extremely high prices, land costs are low and in times of low prices, land costs become extremely high.

If there were no fixed costs of production, there would still be changes in land use, due to differential changes in the costs of production. Where there are fixed costs these differentials in costs become exaggerated; thus, use may shift quite widely over a period of a business cycle, even if all costs other than fixed costs were to change in the same proportion.

Bunce (7) has shown that in times with high prices in relation to costs that investment in land takes place. This is both a problem in variable costs on land in relation to production and a problem of scale of production. By this is meant that if prices are high for barley in relation to variable costs, inputs per acre will be increased as well as number of acres. These may have a residual effect on soil or land. In addition to this, the higher price per hour for labor will mean that leisure will be worth less at the margin in relation to labor. Thus longer hours will be worked which can either result in larger farm units or more intensive production by the addition of enterprises. Since there is an active demand for farmland during periods of high farm prices, and then a shortage of land, the expression of the willingness to work longer will probably have to go to increased investment per acre in terms of additional variable inputs such as better seed, tile and irrigation or into new enterprises to utilize labor such as livestock.

If, however, agricultural prices become great enough in relation to costs there may be an increase in the marginal value of leisure in relation to labor and production actually decrease. This is due to decreasing marginal value of money. This is an explanation of the so-called Florida farmer, who rather than sell some of his land and work at the same intensity as before on the acres he keeps, works all his land at some more extensive use, as cash grain for example, leaving his winters free to go to Florida.

Theory Summary

An attempt has been made in the theory division of the study to explain the relationships that exist between certain factors affecting land use. An attempt was made to explain why farmers chose to remain in agriculture rather than do something else. An attempt was made to explain why farmers choose the size and quality of farms they do. Factors that determine the maximum and minimum size of farm for one individual farmer were discussed.

An explanation was given for why so-called "poor farmers" should be forced to the less productive lands. It was shown further that the so-called "good agricultural land" far from town might be too poor to farm close to the city because of the competition of industry for the services of the farmer.

Land use intensity and some of the factors affecting intensity were discussed. The factors that caused intensity to vary were explicitly stated to be: the ratio of output to input prices, the use elasticity curve for the specific crop and cropping system on a particular natural

land type, input and output transportation costs, factor costs of production, the natural land type, the natural land type pattern and the quality of entrepreneur.

Each intensity factor was considered in turn and some of the implications of changes of each factor on intensity of use were given. Finally the dynamics of the factors were discussed. Rigid costs and changes in price relationships over time were considered. The hypothesis that a system of theory could be developed that was sufficiently like the real world as to explain land use in real situations was proposed. This hypothesis was not tested in this study because of a lack of information on which to base a test.

Relation of Theoretical Work to the Statistical

In the statistical section, effort was made to avoid one pitfall, that of drawing conclusions about the causes of certain observed facts without clear cause and effect evidence being present. Therefore, at many points in the statistical section, note was taken of the fact that no reason for the "why" or "how" of the fact stated could be drawn from the information given. Reference was then made to the theory section which was to follow.

In the theory part of the study a synthetic method of analysis was used to construct a pattern of land use analogous to land use in a real situation. Unfortunately there was no way in this study to test the theory reviewed and developed here.

The theoretical work was given to develop a method of study for such utilization studies as the study of an economic region or sub-region.

It would be folly to say that the statistical division of this investigation bears out the theoretical; it does not. There is no clear evidence presented that there is any relationship between the statistical facts presented and theory. The author believes, however, that such a relationship exists. The only hypothesis that the statistical section proves is that there is a clear difference in use between the natural land types studied.

It is more in the nature of this investigation to attempt to discover what sort of information is needed for improving land use studies in the future than to prove that the statistical portion of this thesis proves the theory part.

It was in fact after two years of collecting and sorting data about the Lansing region that the author came to realize that information necessary to discover the "why" and "how" of land use in the region simply was not available and could not be obtained in less than seven to ten years of intense experimental work. It was from this realization, that the theoretical portion of this study came to be written.

It is felt that before better land use studies can come into being that there must be a clearer realization by everyone doing such studies of the amount and kind of experimental work that must be done in order to characterize land. Studies dealing with the relation of the organization of the individual farm to the economic organization of the economic sub-region are practically non-existent. Characterizing land by its marginal input-output relationship has not been attempted other than in some isolated greenhouse experiments.

Suggestions for Further Research

The most obvious further research to be made as a result of this study would be to test the hypothesis developed. The problem of proving or disproving the theory could be approached in the following way.

First, an economic sub-region similar to the Lansing Region used in this study should be selected. If possible a region larger than the Lansing Region should be used and one in which not more than four or five well-distributed natural land types occur. It would be desirable if several distinct types of farming occurred within the region.

Secondly, the land should be classified, using the natural land type concept, into its natural land divisions. The worker should make a preliminary survey before classification of the land to discover the order of land type that the farmers of the area use in making production decisions. This will usually be based on the size of field. In some cases, however, fields are used for two or even three kinds of land for one crop. For example, if a farmer fertilizes one part of a field of wheat more than another because of a change in land, the order of land classification should be of small enough scale to include this difference.

After the natural divisions of land have been made, the agricultural economist and the soil scientist should set to work to characterize the natural land types by physical input-output relationships. In order to do this properly, all crops under all cropping systems with all additions of inputs applicable to the area in question must be studied.

This research would probably take two forms: the first would be cropping system or crop rotation experiments to which various treatments at all practical levels of intensity of input would be added. For example,

if it appeared from preliminary study that five cropping systems covered most of the systems that had been used in the last thirty or forty years on a given natural land type, probably these five rotations with variations on them would be all that need be studied. To each of these systems could be added fertilizer, tillage, drainage or other land treatments.

The second kind of experiment that would be necessary to characterize physical input-output of a given land type would be complete farm experiments. These could take either the form of an experimental farm in which all levels of inputs were scientifically controlled or the form of statistical studies of actual farms on which a statistical rather than an experimental control could be operated.

The second system of using many actual farms rather than a few experimental farms would have the definite advantage of distribution over the sub-economic region. Thus real effects of transportation cost could be studied statistically. Also there would be an opportunity to observe changes in land use from year to year due to changing economic and technological conditions.

While it is admittedly a very expensive and difficult job to characterize land for its physical productivity, it is one which can be done.

Once the physical relationships of output to input have been determined on any given natural land type, an economic analysis of changes in factor costs and transportation costs with distance from town should be made.

Finally a thorough study should be made of the area as a whole to find complementary land uses existing between land types. Institutional

factors, distribution of capital, industrial opportunity and many other factors affect land use within an area. But in spite of the complicated procedure of explaining land use within a region, the effort made to test the theory developed in this study would undoubtedly be worth the expense.

In this era of controlled production and public restriction of all sorts, the land use planner has need for a keener tool than qualitative analysis to study the whys and hows of land use. If he cannot tell what has caused present use with his present tools, he will certainly never be able to predict future use with any certainty.

In spite of its crude form and its many inconsistencies the author believes that only with an integration of the agronomic and economic sciences in some such theory as the author has developed will much progress be made towards scientifically overcoming the problem of being able to control and direct land use in an area with any degree of success.

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